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ABSTRACT

This is the report of a study designed to develop and test methods of deriving, directly from an analysis of the system or its surrogate, an effective and economical set of skills and knowledge for operating and maintaining a weapon system. Two methods for analyzing electronic weapon systems were developed, one method for the operator task and one for the maintenance task. These methods were then used to establish the content of a training program for the operation and maintenance of the M33 Antiaircraft Fire Control System. A 12-week (400 academic hours) experimental training program was administered to a group of students who were matched in background with a group of students from the standard 30-week (1000 academic hours) M33 repairman course sequence. After graduation from their respective courses, 20 students from the experimental group and 17 students from the standard group were tested as rapairmen. They were tested on their ability to energize, adjust, and trouble shoot the individual parts of the M33 system. Both groups of students scored equally well on this performance test. The researchers concluded that considerable training time can be saved, with no loss in performance skill, using a training course based on the methods developed in this research. (LC)

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Determining Training Requirements for Electronic System Maintenance:

Development and Test of a New Method of Skill and Knowledge Analysis

by

Edgar L. Shriver

Training Methods Division

The George Washington University
HUMAN RESOURCES RESEARCH OFFICE
operating under contract with
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DETERMINING TRAINING REQUIREMENTS FOR ELECTRONIC SYSTEM MAINTENANCE:

Development and Test of a New Method of Skill and Knowledge Analysis

by

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Task FORECAST I

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BRIEF

1. **PROBLEM.** To develop and test methods of deriving, directly from an analysis of the system or its surrogate, an effective and economical set of skills and knowledges for operating and maintaining a weapon system.

2. METHOD

a. New methods of task and skill analysis were developed and used to establish the content of a training program for the operation and maintenance (through fourth echelon) of the M33 Antiaircraft Fire Control System. A 12-week (400 academic hours) experimental training program was administered to a group of students who were matched in background with a group of students from the standard 30-week (1,000 academic hours) M33 repairman course sequence.

b. After graduation from their respective courses, 20 students from the experimental group and 17 students from the standard group were tested as repairmen. They were tested on their ability to energize, adjust, and trouble shoot to individual parts of the M33 system, using both common and special test equipment.

c. The performance test was objective and extensive, requiring nine days for administration to each man. It included about the same number and type of problems that an average repairman (MOS 232.1) would encounter during his first 8 to 12 months in the field.

3. FINDING AND CONCLUSION

a. The students of the experimental and standard courses scored equally well on the postgraduation performance test.

b. In view of the fact that the experimental group had had only 12 weeks of training, as compared with the standard group's 30 weeks, it is concluded that considerable training time can be saved, with no loss in performance skill, using a training course based on the methods developed in this research.

4. **RECOMMENDATION[1] AND IMPLICATION.** Army schools teaching electrical and electronic courses should consider the methods and procedures developed in this study to determine their relevance to existing and future training programs.

---

[1] A recommendation for adoption of the short course developed for MOS 232.1 would be justified from the results of the study. However, as the M33 equipment analyzed in developing the FORECAST method was obsolescent and as MOS 232.1 is a low-density training course, the recommendation is not made.

SUMMARY AND RECOMMENDATIONS

PROBLEM

The general objective of Task FORECAST is to develop methods of accurately forecasting the training demands imposed by new weapon systems. The objective of the first phase of the research, reported here, was to develop and test methods for analyzing electronic weapon systems which accurately define a set of skills and knowledges for operating and maintaining the systems. Subsequent research will test the value of these methods as predictors of future training demands and extend them to other types of weapon systems.

At the inception of this research it was obvious that allocating new weapon systems for use during the initial research phases would be extremely uneconomical. Nevertheless, some system was needed which was of sufficient complexity to present maintenance problems similar to those predicted for future systems. This similarity requirement had to be met to ensure that the results of the study would be applicable to future systems. A system which met these requirements, and which was available for research use at the beginning of the Task, was the M33 IFC. This system was employed during the FORECAST I research. To further ensure the applicability of the research to future systems, the training program developed for the M33 was based on the type of information which had been available before production of the M33 system.

In addition to similarity, availability, and economy considerations, the M33 was used because students were currently being trained in its maintenance. This meant that the performance of these students could be compared with that of students from any training program developed during the research, thus assessing the efficacy of the experimental methods of job analysis.

A joint decision was made in February 1958 by the Office of the Chief of Ordnance, the Ordnance Training Command, and the Human Resources Research Office to test the new methods immediately on an existing electronic weapon system, the M33 Antiaircraft Fire Control System, rather than wait for a new system to become available for the research. The purpose of this test was to determine how much effectiveness and economy could be obtained through the method's increased accuracy in specifying job demands. Economy would be shown in decreased training time and effectiveness in increased job proficiency.

The methods of analysis and the results of the test of the effectiveness and economy of an electronics maintenance course derived from these methods are presented in this report. Further tests will be conducted to determine whether the method's greater accuracy leads to an increased ability of repairmen to transfer their skills from one system to another. This potential has important implications for forecasting because it makes it possible to substitute an obsolescent system for a new one during a certain portion of the training for the new system.

METHOD

Two methods for analyzing electronic weapon systems were developed during the study—one method for the operator task and one for the maintenance task. Both methods identify a set of skills and knowledges and their constituent parts (*cues*, or what a man perceives, and *responses*, or what he does about it) which, when properly learned, form the basis of a logical reasoning process which should lead to effective operation and maintenance of the weapon system. The nature of the cues ranges from intricate symptom pattern discriminations to the illumination of a red light. Likewise the responses range from complex mental deductions and manual skills to the recording of meter readings and pressing of buttons.

Operator and maintenance activities require different analytic methods for the following reasons:

(1) System developers build operator's cues and required responses into the machine in the form of displays and controls. However, in the maintenance task, the cue-response structure had to be imposed as a part of the method of analysis because of the almost infinite variety of malfunctions and their effects.

(2) The operator method identifies and defines all cues and responses incorporated in the system by its designers. The method for analyzing the maintenance task involves rules for selecting and defining certain cues and responses rather than others.

The methods of analysis were used to derive sets of skills, knowledges, cues, and responses sufficient for operating the M33 Antiaircraft Fire Control System. Skills, knowledges, cues, and responses were also derived for performing first and second echelon maintenance and third and fourth echelon repair. In addition, a "story" was developed which provided the logical structure for trouble shooting deductions as well as a way of talking about the cues and responses, many of which were pictorial in form.

The sets of M33 cues and responses derived from these analyses were combined into skills and knowledges and given to students in a 12-week experimental electronic repair course. These students came to the course directly from Army basic training. They were matched in background (years of education, and Electronics and General Technical aptitude scores) with a group of students receiving the standard 30-week training for third and fourth echelon repair of the M33 system (Heavy Fire Control Equipment Repairman, MOS 232.1). This course sequence consisted of basic electronics training at The Signal School and advanced training at The Ordnance School.

Instructors of both groups used the same techniques of instruction, described in FM 21-6, *Techniques of Military Instruction*. The student-to-instructor and student-to-equipment ratios favored the 30-week standard group. Instructors of the standard group had much more teaching and electronic experience than did the instructors of the experimental group.

After graduation 17 students from the standard group and 20 students from the experimental group were tested on an objective repairman performance test requiring nine days. This unusually long and comprehensive test was constructed in an effort to increase both representativeness and reliability of the test. The test required the students to trouble shoot for malfunctioning parts in as many different chassis as would the average repairman during his first 8 to 12 months in the field. It measured the subjects' ability to energize, adjust, and identify the malfunctioning parts (e.g., resistors, capacitors) in the electronic portions of the M33 system, using common and special test equipment. A large number of work samples from the actual field job were included to improve estimates of true student ability.

FINDING

Despite the fact that the experimental training time was less than half the standard training time, there were no practical differences in proficiency between the experimental and the conventionally trained groups.

CONCLUSIONS

Since the experimental group performed as well as the standard group, it is reasonable to conclude that the specific set of cues and responses used in training the experimental group was as effective as the material used with the standard group.

The finding becomes more striking when it is noted that the study was designed to make all identified factors affecting group performance—personnel, teaching techniques, and cost elements—either equivalent or favoring the standard students. The critical nonequivalent factor was the experimental variable, namely, the content of the training programs.

It should *not* be concluded from the experiment that the elimination of The Signal School course in basic electronics was the primary difference between experimental and standard training. The difference between the experimental course content and the standard content may be characterized in many ways, one basic way being developed in the report. Whatever the nature of the difference, the methods of skills and knowledge analysis developed in the research are designed to produce a standard method for determining course content. This means the methods can be applied to other *systems* to obtain a course content; they do not depend on adding or subtracting "building blocks" from an existing course. It is also important to recognize that the evaluation of the method is based on performance, so no purpose is served in making a detailed comparison of the standard and experimental course content.

Since the rules developed for identifying the set of skills and knowledges were designed to have generality—and indeed, on the three M33 subsystems, demonstrated generality—it is expected that similar sets of skills and knowledges can be produced for other electronic systems. It also appears likely that the general methods of analysis would be as effective for other electronic systems as they were for the M33, but this can be determined with certainty only by testing each of the other systems in the same way the M33 was tested. Experimentation on this scale is impractical. However, as the research is implemented and additional systems prove suited to the cue-response method, the confidence that the methods can be used to produce effective and efficient training programs for still other systems will continue to increase.

In view of the far-reaching implications of applying these findings in operational situations, it would be desirable to obtain additional evidence as to the value of the analytic methods in combination with mock-up equipment before the Army undertakes implementation on future weapon systems. (These tests are being conducted in Subtask II of FORECAST and findings will be presented in a separate report. The tests include a measure of the ability of students to transfer skills and knowledges learned on one subsystem to another subsystem.)

RECOMMENDATION[1] AND IMPLICATION

Army schools teaching electrical and electronic courses should consider the methods and procedures developed in this study to determine their relevance to existing and future training programs.

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[1] A specific recommendation for the adoption of the short course developed for Heavy Fire Control Equipment Repairman (MOS 232.1) would be justified from the results of the experimental evaluation in this study. However, as the M33 equipment used as the basis for analysis in developing the FORECAST method was obsolescent and as MOS 232.1 is a low-density training course, the recommendation is not made.

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DESCRIPTION OF THE RESEARCH

DETERMINING TRAINING REQUIREMENTS FOR ELECTRONIC SYSTEM MAINTENANCE:

Development and Test of a New Method of Skill and Knowledge Analysis

Chapter 1

DEVELOPMENT OF THE METHODS OF ANALYSIS

OBJECTIVE AND RESEARCH APPROACH

The objective of the FORECAST I research was to develop and test methods appropriate for analyzing such military jobs as that of the Heavy Fire Control Equipment Repairman, MOS 232.1. This subtask was the initial portion of a research program to develop methods of accurately forecasting the training demands imposed by new electronic weapon systems.

It was obvious at the outset that it would be highly uneconomical to allocate new weapon systems for use during the first phases of the research. However, some system which was complex enough to present maintenance problems similar to those predicted for future systems was needed. This similarity requirement was especially important, to make certain that the results of the study would be applicable to future systems. The M33 IFC system met these requirements, and was available for research use when the Task was initiated; this system was utilized for FORECAST I. As a further means of insuring the applicability of the research to future systems, the training program developed for the M33 was based on the type of information available before the system had gone into production.

Another reason for using the M33 system was that students were currently being trained in its maintenance. The performance of these students could therefore be compared with students trained by any experimental methods, to evaluate the methods of job analysis developed during the research.

Many methods of analyzing jobs have been developed in the past. Each has been formulated to meet particular requirements, such as for use in job (or MOS) descriptions, selection, pay scale determination, or training. These methods have been known by such names as task and skill analysis, skills and knowledges analysis, and task and equipment analysis.

Most of these methods are of use in modifying an existing job rather than in creating a new job; the source of data is generally that of observing a man perform on an existing system. Such characteristics invalidate these methods for use in forecasting a complete set of job demands imposed by weapon systems of the future. These characteristics and others are discussed in a HumRRO Staff Memorandum.[1]

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[1] Edgar L. Shriver. *A Theoretical Approach to Forecasting the Training Demands Imposed by New Army Weapons Systems,* Staff Memorandum, Training Methods Division, Human Resources Research Office, Alexandria, Va. (published in Washington, D.C.), December 1956.

In the present study, methods were developed that were designed to derive, from a system's preproduction information, a set of data that would be sufficient for the initial establishment of a complete training program for repairing and operating that system. The development of these methods, their application to an existing radar system, and the testing of the repair proficiency of men trained in the content derived by the methods are described in this report.

It has been noted that one unique requirement of methods to be used for forecasting purposes is that they make it possible to analyze a system before it goes into production, rather than after it is in field use. Therefore, the research was directed toward identifying necessary skills and knowledges from a direct analysis of a weapon system, or its schematics and blueprints, rather than from observations of already established job performance.

A second requirement is that the description of the skills and knowledges be sufficiently detailed and exact for training purposes. For purposes such as selection, it might be sufficient to describe a skill as "pushes buttons"; from the task description it could be deduced that an applicant should have ten strong fingers. However, for training purposes there would have to be information regarding the circumstances under which the man should push one button rather than another. This means the analysis must be designed to produce detailed descriptions of differences in task situations.

A third requirement is that the methods produce sufficient information for establishing a complete training program. Some types of activity analysis might be appropriate for modifying an existing training program but would be useless for establishing the entire content. For instance, a method of analysis might involve a procedure for counting the number of times various test equipments were employed under field conditions. This information would be appropriate for revising a training program to include formal training for certain test equipment but it would not be sufficient for establishing a complete initial training program. Consequently, the FORECAST methods are designed to establish the basis for a complete initial program rather than for shifting emphasis in existing programs. This does not mean that a program should not be modified after it is established by FORECAST methods.

A fourth requirement is that the methods should not depend on the adequacies and inadequacies of the engineering plans for constructing test equipment, equipment displays, and within-system check points. The methods of analysis were designed to provide information appropriate for guiding the construction of sufficient displays, check points, and so forth, for effective testing of the system. However, in the event that the plans finally executed for system design do not provide sufficient information, the analysis must provide the basis for obtaining needed information from points in the system that were not originally designed for information collection.

A fifth requirement is that the methods of analysis be applicable to as many systems as possible. To meet this requirement the development of the methods reported here proceeded from certain general guide lines or propositions. These are believed to have broader application than in the specific set of skills and knowledges produced in this study.

The two basic propositions that guided the development of the FORECAST methods of analysis are:

(1) Any job, including those involving logical reasoning, may be described in terms of certain cues which a man receives through his senses, and responses which he makes to accomplish his job.[1]

(2) Learning the cues and responses and the cue-response associations which describe the job equips the man for doing his job better than learning any other type of information.

From these propositions two methods have been developed to meet the Task objectives. One is designed for operator tasks, the second for maintenance tasks. These methods deal with establishing the cues and responses which accurately define and are the constituents of the knowledges and skills[2] needed for effective operation and maintenance of the analyzed system. The major portion of the research effort has been devoted to developing and validating the second method.

Both methods of analysis, by increasing the accuracy of determining job requirements, establish a much smaller number of knowledges and skills (in the form of cues and responses) than are taught in traditional training programs. Whether this smaller number does represent increased accuracy and is sufficient for doing the job effectively is one question asked in this study. The second question asked is whether the reduction in the number of things to be learned is economical, by leading to substantially reduced training time.

Regardless of the finding of the study, it should be remembered that none of the dignity of a job is lost through the use of terms such as cue or response to refer to the job element. The term cue is very general and is meant to refer to extremely intricate patterns for symptom discrimination as well as to, for example, the illumination of a red light. Likewise the term response is meant to refer to the most complex concept or manual skill as well as to, for instance, pressing a button. The terms used do not make the repairman's job unimportant or simple. There are still the same complex discriminations and associations in the repairman's job after the analysis as there were before. The only effect the analysis can have is to specify the nature of a complex discrimination or association in terms that would be familiar to a student. The use of familiar concepts to define more complex concepts is generally considered essential to undertsanding. The purpose of the analysis is to increase the potential for understanding a system rather than to degrade the repairman's prestige.

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[1] "Cues" are the aspects of the system's functioning which a man can perceive and use to make the "responses" which are needed to keep the system operating within tolerance limits. The responses may be physical, such as pushing buttons, or conceptual, such as choosing one procedure rather than another.

[2] Jobs are commonly analyzed in terms of the "knowledges and skills" necessary to perform the job. These categories are quite general, and for training purposes a knowledge or a skill almost always has to be further analyzed into specific cues and responses.

DEVELOPMENT OF THE METHOD FOR ANALYZING THE OPERATOR TASK

A Description of the Operator's Task

The radar operator can do only what the equipment lets him do. He is limited in his actions, which must be performed in a certain sequence and at certain times or the machine will not operate within its tolerance limits.

Cues which the operator perceives are defined by the display presentations of the radar system—lights, meters, buzzers, scopes, and so forth. The required responses are accomplished by operating the machine controls—such as handwheels, buttons, and knobs. When the operator makes a required input to the machine through one of these controls, no alternate input assures continued operation within tolerance limits. Displays and controls, and the relationships among them, are built into the radar system. These determine the cue-response combinations which describe the operator task.

If the machine has been properly "human-engineered," each requisite input will be preceded by a distinctive display condition. For the operator this display condition is a cue. Once the operator has learned to discriminate that cue from all others, and to make the proper input-producing response to it, he can then make the proper response at the proper times.

The feedback loop model depicted in Figure 1 is useful for describing the man-machine system. The machine produces a display condition (input to the man) which is perceived as a cue by the man who, in turn, processes it into a response. The operator's response (input to the machine) causes the machine to continue operating in such a way as to produce both the final output(s) of the system and further changes in the display condition.

The pattern of changes in cues and responses, or the interrelations among them, represents a theory that concerns the over-all functioning of the system. It deals with the relationships among the subdivisions of

Man-Machine System

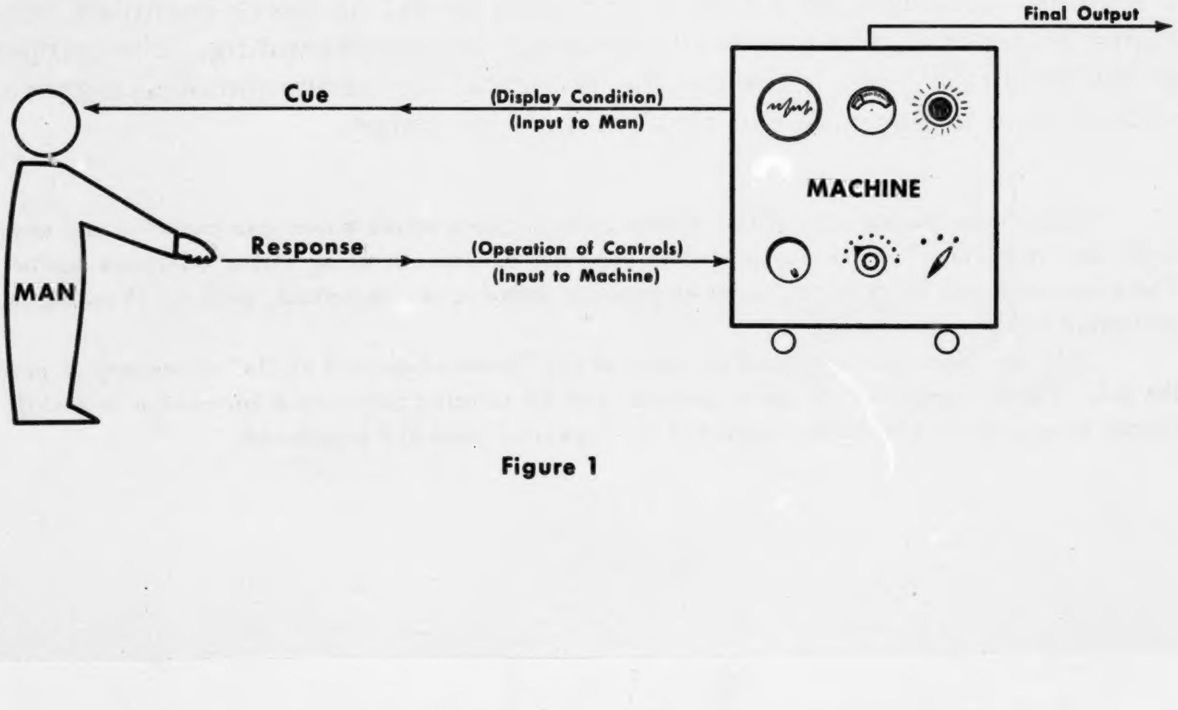

Figure 1

the system that produces the cues rather than the actions of the electrons within these subdivisions. To distinguish the theory of the over-all functioning of the system from the electron theory, it has been called the "technische handlung," or the nearest English translation of that term which is simply "story."

Thus, through the mediation of a story which represents all the associations between the cues and responses, the human operator learns to convert cue information into response action. In this research it has been hypothesized that learning to accomplish this conversion process enables the man to do his job. He does not have to know how his cues are produced. He must be able only to tell one from another and, by knowing the correct pattern of associations, make the proper responses to each cue. Therefore, he need not learn the processes internal to the machine.

This way of viewing the man-machine system offered guide lines for establishing the knowledges and skills a man needed for operating a given system. It indicated three training requirements for the man portion of the man-machine system:

(1) The operator must learn to identify each display condition as a cue different from every other.
(2) He must learn to make each response which constitutes an input to the machine.
(3) He must associate each cue with its appropriate response.

These guide lines suggest the nature of the operator training material. They do not indicate a method for identifying cues and responses in a given situation. A deductive step was needed between the general propositions and a specific method for establishing cues and responses. Defining this step was the substantive work of this research. The products of this step are methods, or rules, for making cue-response analyses of electronic systems.

The Cue-Response Method of Analysis for the Operator Task

A method for analyzing a machine to describe all cues and responses necessary to its proper functioning was developed in the present study. This "cue-response analysis (operator)" method was applied to the M33 Antiaircraft Fire Control System and each operator task was analyzed.[1]

The first step in the analysis is to define each input needed by the machine, quantitatively and qualitatively, in machine terms. For instance, one input (response) might be defined as "turn knob A 1/4 turn clockwise," and knob A would be identified on a photograph of the machine. A response definition such as "turn knob A" or "turn knob clockwise" would not be acceptable; "turn knob" would be useless, unless the direction and amount were obvious or noncritical with respect to machine tolerances. The response must be defined so precisely that a previously untrained person can distinguish the appropriate action from all inappropriate actions on the basis of the description in the analysis. The quantitative aspect of the description may be considered as indicating the adequacy of the response. The "1/4 turn" in the above example is such an indication. Other examples are "turn knob A clockwise until it clicks" and " . . . until light C goes on."

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[1] Samples of this type of analysis are presented in Appendix A.

The next step describes cues in equally exact terms. Cue descriptions are placed opposite response descriptions in tabular form. The definition of each cue must be sufficiently accurate so that this cue is discriminable from all other cues produced by the machine. The definition need not be verbal; it may be pictorial or in any form which can be used for communication between people.

Finally, the association between each cue and the required response must be made clear (usually listing the cue and associated response side by side in the analysis format is sufficient).[1]

With operator tasks certain responses normally follow in an invariable order. The indication of the adequacy of one response constitutes the cue for the next. Such "chains" are frequent in operator tasks, but there are many "breaks" in the chain. For instance, in the M33 system the response of turning up magnetron voltage invariably follows application of heater current. However, green light A must go on before magnetron voltage is applied, and that light is delayed by five minutes.

There are some points in the chains where alternate cue-response chains are encountered, and the machine indicates the proper path. In a few instances the machine will operate equally well regardless of which chain is followed. In these cases rules for choosing a chain are established by the manufacturer or the Army user. These rules may be arbitrary, or they may be governed by one system operating in a common network with other systems.

In all cases cues, responses, and cue-response associations are determined by specific equipment requirements. The main objective of the operator task analysis is to specify and describe in detail those cues and responses critical to equipment operation. A secondary objective is to avoid introducing information irrelevant or redundant to job requirements. In instances where the displays of the machine impose a small amount of redundance, the effort is made to take it out through the analysis.

DEVELOPMENT OF THE METHOD FOR ANALYZING THE MAINTENANCE TASK

A cue-response method is suitable for analyzing M33 operator jobs, where the task is defined by the equipment itself. The maintenance task, however, presents a different situation, since it is not currently feasible for system developers to build equipment for easiest maintenance. Therefore, rules developed for analyzing operator tasks are

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[1] The format described has been found to be useful; others are probably equally effective. Usually the format is changed for oral presentation in a classroom. The second example of an analysis in Appendix A is in a format appropriate for the classroom.

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a resistance value which changes (generally to zero or infinity) when the part malfunctions. Since the correct value for each part is known, a measured change from that value indicates a malfunction. This last step is called "part" identification. It is also followed when the nature of the circuit attached to a tube pin is such that the resistance of the circuit will not change when a certain part in the circuit malfunctions. Under this condition all parts which are "hidden" in the tube pin circuits are tested individually.

To recapitulate, the four steps in identification are:

(1) Symptom to symptom area
(2) Gray Box
(3) Tube chain
(4) Part

These four steps are efficient isolators of malfunctions. When the steps are performed in this order, the greatest number of parts are eliminated from consideration in the shortest time. This does not mean that the steps must be taken in this order. In the extreme case the last step, measuring the resistance of each part, could be taken first. This eventually would lead to the correct identification of the malfunctioning part, but much time and effort would be required to measure each part rather than large groups of parts.

There is a characteristic of most electronic systems that can be utilized independently or as an integral part of other methods of trouble shooting, or it may be completely ignored. A new chassis can be substituted for one assumed to contain the malfunctioning part; if the assumption was correct, substitution of the new chassis causes the equipment to again function properly.

Signal flow channels and chains weave in and around the radar system; they go through many chassis. Some chassis have several channels going through them, and others have only portions of one channel. Chassis exist because of the obvious physical convenience of handling several small pieces of equipment rather than a single large one. Chassis are connected to the system through pressure contacts, so they may be removed from the equipment without time-consuming unsoldering of connections.

The characteristics that have been mentioned are the key elements of the electronic (radar) system. Certain symptoms are caused by any one of certain identified parts and no others. There are a sufficient number of these symptoms that the entire system may be divided into groups of parts that will produce one of these symptoms and no other. In like manner there are mutually exclusive subgroups in each group, and each subgroup produces indications unique to the parts in that subgroup. Similarly, within each subgroup there are still further subdivisions and finally within them are single elements which consist of a throw-away part (e.g., resistor or capacitor).

Maintenance men have used symptoms and indications in their trouble shooting for years. However, a method has not been developed for systematically identifying each symptom cue and response action. The method of analysis described in the following section clearly defines a way to trouble shoot. End-of-channel information is used first because it is immediately available from inspection of built-in indicator displays and effectively discriminates between good and bad channels. Sidetracking action by portable test equipment is generally used next, as each measurement checks a large group of parts. In the final steps relatively short chains of parts and individual parts within the chain are measured by resistance meters. This sequence results in an efficient trouble shooting procedure which logically seems easy to follow, highly reliable, and economical of trouble shooting time.

The Cue-Response Method of Analysis for the Maintenance Task

Now that the electronic system has been described, the method developed for analyzing maintenance tasks can be presented more easily. The cue-response method of analysis for maintenance tasks consists of rules[1] for developing a conceptual structure of the system which is not evident from its physical structure.

The rules specify how the system is to be divided into four (and only four) conceptual levels. These levels, from the grossest to the finest are "channel," "channel segment" (also called "Gray Box"), "tube chain," and "part." In the M33 Track subsystem, for example, there are about 25 channels, 100 channel segments or Gray Boxes, 1,000 tube chains, and 10,000 parts. These approximate numbers are also representative of other major Army radar systems such as Nike and Hawk.

The analysis method specifies how each cue and response within a given level is to be defined. Cues at each level are defined in terms of (1) their characteristic appearance, (2) tolerance limits of this appearance, and (3) the technique of obtaining the cues, including their location. Responses are defined in terms of components or groups of components which produce the defined cues. In other words the responses at each level are defined in terms of the next finest level. For example, channel is defined in terms of channel segments, and channel segments in terms of tubes and resistance readings on tube pins.

The description of responses implies collecting cues actively either by observing displays or taking wave form readings. The cue obtained is associated with the next response. This response is expressed in terms of where the next finer level cue will be obtained. Obtaining that cue will, in turn, require the use of some form of test equipment. These steps are summarized in Figure 2; the cues are shown in the first column, the responses in the last, and the materials used to convey the information to the student in the middle column.[2]

A resume of the nature of cues and responses defined at each of the conceptual levels may further clarify the use of cues and responses in maintenance tasks.

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[1] A summary of these rules is included in Appendix B.

[2] The Department of Army Technical Manuals used as sources were TM 9-6092-3-1, *Anti-aircraft Fire Control Systems M33C and M33D; Schematic Diagrams*, October 1956; TM 9-6092-3-2, ______; *Voltage and Resistance Charts*, January 1957.

Cue-Response Trouble Shooting Method

Cue (Created by Malfunction)	Source of Cue-Response Information	Response (What is Malfunctioning)
1. Symptom	Block diagram →	Group of Gray Boxes
2. Gray Box output (wave form or voltage)	Gray Box check points →	Particular Gray Box
3. Tube check	Tube tester →	Individual tube (replace bad tube)
4. Pin resistance (on tubes in Gray Box)	Voltage and resistance charts, for the M33 radar system, TM 9-6092-3-2 →	Group of parts attached to pin
5. Resistance value of part (in pin group)	Schematics, for the M33 radar system, TM 9-6092-3-1 →	Particular part (replace part)

Note: If all pins in Step 4 give correct resistance readings, the response is Step 5 for hidden parts rather than for parts in a pin group.

Figure 2

(1) Cues at the first or grossest level are symptoms. The response to a symptom cue is to select from several channels the one that is malfunctioning.[1] The interplay of cues and responses used in the selection process constitutes reasoning.

(2) At the second level, cues are readings (wave form or voltage) obtained at the terminal points of conceptually defined segments (Gray Boxes) of the malfunctioning channel. The response to such a reading is to select the particular channel segment that produces an out-of-tolerance output when it has a within-tolerance input. This selection process also involves reasoning but this reasoning is not as difficult as that in step (1).

(3) Cues for the third level are readings (resistance) obtained at the terminal points (tube pins) of the chains within the malfunctioning channel segment. The response to a third-level cue is to select the chain that produces an out-of-tolerance reading at a tube pin. If an out-of-tolerance reading is not obtained, this is the cue for the response of testing for hidden parts.

(4) For the fourth or finest level, cues are resistance readings of replaceable parts obtained by measuring across each part within the malfunctioning tube chain. The response to a fourth-level cue is to select an individual part that has an out-of-tolerance resistance reading. The malfunctioning part can then be replaced.[2]

A training program based on this type of analysis has as its content (1) exact descriptions of all responses repairmen must make

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[1] This is an example of a conceptual rather than a physical response.

[2] When the malfunctioning hidden part is an open capacitor (likelihood of occurrence is less than 2%), there will be no indication at level three. The lack of an indication is itself the cue for measurement of all capacitors in the segment with a capacitance analyzer which will identify the faulty capacitor. After the response at level two the tubes in the segment should be checked. If no malfunctioning tube is found, the remainder of the steps are performed.

and (2) exact descriptions and tolerance limits of all the cues that indicate which responses should be made. Descriptions of cues and responses in the program are presented in many forms, including block diagrams of channels, pictures of wave forms, charts of voltage and resistance readings, and outlined schematics of parts within a segment.[1] The training program also tells how to use both common and special test equipment for obtaining cues.

The foregoing paragraphs describe "how" the cue-response method of trouble shooting was organized. Another way of describing how this was done is in terms of the general approach taken in this study. The model used to describe the FORECAST approach to analysis of the operator task (Figure 1) is also appropriate for the maintenance task. The man-machine relationship is considered as a feedback loop system. The machine produces information, such as a symptom, wave form, or voltage, that serves as an input to the man. The input is perceived as a cue by the man, who processes it into a response, such as placing an oscilloscope probe on one particular check point. The response causes the machine to furnish another cue, such as a wave form reading. This cue, in turn, allows the man to make further responses, such as measuring resistances on certain tube pins.

The maintenance man processes or converts cue information into response action. He does this by learning the appropriate response for each cue, and then by making that response each time he perceives the cue. According to the propositions on which this research was based, learning this process is a sufficient basis for the man to do his job. The man does not have to learn electronic processes internal to the machine; he needs to know only those processes internal to himself, so to speak.

This general approach, then, can be applied as well to the maintenance task as to the operator task. The difference in the two methods of analysis lies in the definition of specific tasks. Maintenance analysis must provide a conceptual structure not required for operator analysis.

Rules for analyzing the maintenance task must include a means for breaking the channels into segments; a set of associated cues and responses can be established only by establishing one set of segments. The rules must also establish which machine indications will be used as cues. For instance, the present method of analysis does not use odor or frequency of malfunction as cues. This does not mean that such cues cannot be incorporated in a man's repertory, but he is not originally trained to use these potential cues because they are redundant with respect to those defined by the cue-response analysis. Rules for selecting one cue rather than another are based not only on appropriateness of the cue but also on its reliability and the ease with which it can be discriminated from other cues.

The most important fact about the rules is that they are based on the general guide lines already discussed. Since the rules are consistent with more general principles, they are likely to have application beyond the situation in which they are tested. They are not likely to be bound solely to the system in which they were first applied. It is also possible that this generality will have the effect of creating training content that is common to a number of different weapon systems. If this proves true in further FORECAST research, men can be trained on an obsolete system to maintain a new high-priority system. Only a minimum of familiarization with the new system would be needed.

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[1] Samples of these materials may be found in Appendix C.

If we wanted a new bridge built, we would not ask a physicist to do it even though he had more basic and general knowledge than an engineer. We would ask the engineer to build it, for the engineer's knowledge is of just the proper generality for this job. So it may be that the cue-response approach provides a better level of generality for general trouble shooting than does theoretical electronics.

The Standard Approach to Trouble Shooting Training

The way in which the experimental program differed from the traditional should be noted here. Members of the FORECAST staff did not base their work on traditional courses. The present study differed from the usual type of HumRRO training research in that the research staff did not attend any traditional course classes and was not familiar with the procedures and content used in them. Methods used to derive training content in the experimental program are based entirely on the analysis of equipment or its surrogate and do not depend in any way on classroom or field observation of present training or operations. Traditional graduates were used in this study only to provide a performance yardstick. In the approach used in this research there is no interest in comparing or analyzing the content of traditional courses as such.

The traditionally trained man is taught the theory underlying the unobservable inner workings which produce the various signals of an electronic system. He learns of the electronic effects produced by each component, how signals are changed as they pass through their channels, and how elements within tubes establish tube characteristics. The traditional method is designed to teach the student general electronic information. However, it does not specifically equip him to deal with cues and responses.

In addition to learning electronic theory, the traditionally trained student obtains some experience in operating equipment. During this training he is exposed to symptom cues and can learn when and how to make appropriate responses. In this activity traditional and cue-response instruction are similar.

Procedures for Analyzing the Computer Subsystem

The Computer subsystem of the M33 requires separate treatment in analysis of the maintenance task because of certain characteristics which distinguish it from the other (radar) subsystems. First, the various computer signal channels converge to a greater extent than those in either the Tracking or the Acquisition radar subsystem. Also, the computer signal generators produce signals which are constantly changing. They cannot be effectively measured while the computer is in operation. Because of this, visible signals at terminal points cannot be judged as correct or incorrect since values obtained vary with the changing output signal generators and the state of the parts in the channel.

To alleviate these problems the system designers built a trouble shooting procedure into the computer as a series of operational tests. These tests involve special signal generators which automatically insert known signals at given points. Cues and responses produced by these known signals meet the requirements of the operator task analysis. The built-in tests follow a specified order. Machine cues as well as operator responses are structured by the computer itself. Application of the "operator" method of analysis in this study resulted in detailed descriptions of how to perform the several tests and a list of cues and responses appropriate for each test step.

The similarity between computer trouble shooting and the operator task ends when the cues lead to a malfunctioning chassis. Because the chassis of the computer are generally small and may be considered as comparable to a channel segment, trouble shooting skills developed in the last two steps of the maintenance procedure (pin readings and resistance checks) are applicable.

For the M33 computer there are three major operational test series and several secondary tests. Each test checks out a well-defined portion of the computer. In this respect each test may be compared to a symptom indication in the maintenance trouble shooting procedure.

With the computer, however, the area checked by each test is defined by the system designers. In the other subsystems the maintenance method of analysis had to be used to define specifically the areas that were checked by each symptom indication.

Chapter 2

VALIDATION OF AN EXPERIMENTAL PROGRAM BASED ON THE CUE-RESPONSE APPROACH

DESIGN OF THE EVALUATION PHASE

The second phase of the FORECAST I study involved an evaluation of the two methods of analysis produced in the first phase. Although these methods were designed to be effective, economical, general, and reproducible, and to have forecasting potential, the Ordnance Corps and HumRRO decided that this phase of the Task would test only the effectiveness and the economy of the methods. Other studies will obtain direct evidence regarding generality, reproducibility, and forecasting potential and will be the subjects of later reports.

To evaluate the effectiveness and economy of the methods, a simple research design was adopted. It required the training of two groups of students; one group was given the 30-week conventional training sequence,[1] and the other a 12-week[2] experimental course derived from the methods of analysis. These two groups of students were then given an extensive proficiency test consisting of samples of the performance required in the M33 repairman's job (MOS 232.1).[3] The performance level of the conventionally trained group was the standard against which the experimental group was compared. This comparison indicates the effectiveness of the experimental training program and the cue-response methods which produced it. A comparison of the lengths of the two courses indicates the economy of the cue-response content of the experimental training program.

Insofar as possible, major factors affecting the performance of these groups, such as quality of instruction and quality and motivation of students, were kept equal or favoring the standard students. The only exception was the course content—the experimental variable.

Of course, results could also be influenced by uncontrolled factors. In all studies, numerous factors are uncontrolled because they are considered relatively unimportant. The importance of these factors is estimated in terms of the effect they would be likely to have, in comparison with the effect of the experimental variable. The physical sciences provide an example. When strips of steel are taken to the standards room to be tested for tensile strength, temperature of the room is one factor that is usually not controlled. It is known that temperature may affect tensile strength, but it is also known that important tensile strength differences could not be attributed to room temperature changes.

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[1] This sequence consisted of instruction at The Signal School, Fort Monmouth, N.J., and The Ordnance School, Aberdeen Proving Ground, Md.

[2] This 12 weeks was the length of the entire experimental training. The student input to the course came directly from Army basic training.

[3] The MOS description for this job is given in Appendix D.

For the same reason, many factors—such as temperature, humidity, student diet—were not controlled in the present study. This is not to say that these factors are unrelated to student performance. It means that in the judgment of the experimenter the size of the effects attributable to such factors was not of the same magnitude as the effects of course content or training time.

In the present study a 60 per cent reduction in training time is attributed to course content. It is unlikely that uncontrolled factors would combine to yield as great an effect as this. However, the reader is not wholly dependent on the judgment of the experimenter in these matters. It is the responsibility of the experimenter to make explicit the factors that have been controlled. The reader may then judge for himself whether there are uncontrolled factors which could have had an effect as large as the one found. The controlled factors for the present study are described in this chapter.

If the important factors are controlled and experimental students perform as well as those from standard classes, it is reasonable to conclude that the specific set of cues and responses used in training them is no less effective than the materials used in the standard course. Since the general rules for identifying the set of cues and responses can be specified, similar sets of cues and responses for other electronic systems can be produced. We cannot be absolutely certain that cues and responses produced by the general methods of analysis will be effective for other electronic systems without testing every system in the way the M33 was tested. Testing on this scale is impractical. However, the more systems that prove adaptable to the cue-response method, the greater will be the confidence that the methods are sufficiently general to produce effective and economical training programs for still other systems. Future research will provide data on other systems that should help the military planner who must decide whether to implement the methods on a broader scale.

SELECTION OF GROUPS FOR THE STUDY

When the study began, 21 students were in the standard course sequence (Basic Electronics course at The Signal School, Fort Monmouth, and advanced course at The Ordnance School, Aberdeen Proving Ground) for the M33 repairman MOS. These students, who represented the entire training load in this MOS during the period of the study, comprised the standard group. Seventeen were tested at the end of training; four were not tested because of failing the standard course or for other administrative reasons.

Background information—Electronics and General Technical scores from the Army Classification Battery, and years of civilian schooling—were obtained for the group. These three factors are the most generally accepted indicators of aptitude for electronics repairmen.

Students selected for the experimental group were matched with the standard group not man for man but so that the resulting frequency distributions and average scores would be as similar as possible.

Selections were made from 200 casual troops recently arrived from basic training and awaiting assignment at Aberdeen Proving Ground. Twenty-four students were selected for the experimental group, as some attrition was expected. Four of them failed to graduate.[1]

The frequency distributions for both groups, presented in Table 1, indicate the similarity between standard and experimental groups[2] on the three background variables.[3]

Table 1

Frequency Distributions of Standard and Experimental Students on GT and EL Scores and on Years of School[a]

Factor	Number of Students	
	Standard (N=17)	Experimental (N=20)
EL Scores		
85-94	1	5
95-104	0	3
105-114	7	5
115-124	5	4
125-134	2	2
135-144	2	1
Mean Score	114.8	108.4
GT Scores		
100-104	1	2
105-109	2	2
110-114	3	5
115-119	6	7
120-124	2	1
125-129	2	2
130-134	1	1
Mean Score	116.2	115.5
Years of School		
10	1	2
11	1	4
12	10	14
13	1	0
14	3	0
15	1	0
Mean	12.3	11.6

[a] Four of the 21 students in the standard training course and four of the 24 students selected for the experimental group were not given the proficiency test because of failure to graduate or for other administrative reasons. The students not tested are not represented in this table or any of the analyses.

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[1] In order to match the attrition rate in The Ordnance School portion of the standard course sequence, the Task officer selected the students to be failed on the basis of classroom and laboratory observations and tests.

[2] Nongraduates are excluded.

[3] The data on the three background factors for each student are listed in Appendix E.

It was not possible to keep motivation of the two groups equal. An Army student normally works toward an MOS. The standard group worked toward and received the MOS 232.1, while the experimental group worked toward and received the MOS 230. The experimental group found that their MOS was not so highly valued as that of other students. After this became known, toward the end of the course, experimental students asked many questions as to why they were not receiving the same MOS after being trained to do the same job. To the instructors and HumRRO researchers it was clear that the motivation of the experimental group decreased because of the lower prestige value of their MOS.

This decrease in motivation did not result in loss of general interest. In a questionnaire given shortly before graduation all students indicated that their interest in the electronics field had increased during the course. More than one-fourth of them indicated that they would reenlist if they could continue in the field.

THE EXPERIMENTAL TRAINING PROGRAM

General

Part of the experimental training program was developed through a series of pilot studies, conducted in Washington and at Aberdeen with civilian and military subjects. These studies were used to try out elements of the cue-response approach, estimate optimum training periods, experiment with training aids of various types, and clarify other problems of both training and evaluation. They also served to train the instructors for the validation study itself. These pilot studies are summarized in Appendix F.

Experimental training was administered at The Ordnance School at Aberdeen. The course was planned for a 12-week period. However, the final pilot study indicated that the students differed in speed of learning, and that these differences appeared related to GT scores. Because a staggered graduation would make it easier to administer the long (nine-day) performance test,[1] the original group of 24 students was divided into a high and a low GT group. The high group was trained for 10 weeks and the low group for 12 weeks.[2] (The groups were later combined for data analysis, since differences in their performance test scores appeared insignificant.)

A comparison of the academic hours (excluding nonacademic time) in the experimental and standard courses is presented in Table 2, and a complete schedule for the experimental course is given in Appendix G.

The teaching techniques used with both groups were the standard Army methods of instruction, set forth in Field Manual 21-6, Techniques of Military Instruction.[3] This manual is presumably followed in all Army schools.

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[1] Described later in this chapter.

[2] The two groups were originally scheduled for 8 and 10 weeks of training. After six weeks of instruction, two weeks was added to the course for each group, to allow more opportunity for integrated system performance.

[3] Department of the Army. *Techniques of Military Instruction*, FM 21-6, May 1954.

Table 2

Breakdown of Academic Hours by Training Subject and Groups

Subject	Group Standard 30 weeks (N=17)	 Experimental 10 weeks (N=10)	 Experimental 12 weeks (N=10)
Basic Electronics Topics[a]	360	40	40
Radar Principles	56	6	6
Power and Distribution	26	16	20
Acquisition Radar			
Conference	69	22	21
Laboratory and PE	81	49	49
Track Radar			
Conference	65	22	38
Laboratory and PE	71	38	61
Computer			
Conference	61	30	26
Laboratory and PE	80	46	40
Integrated System Performance and Ord 6	110	69	117
Miscellaneous	46	25	23
Total	1,025	363	441

[a] In the experimental course this item covers certain topics, such as color codes, nomenclature, and multimeter operation, which were also taught in The Signal School Basic Electronics course. Many other topics were taught in the 360 hours of The Signal School course. The 40 hours in the experimental course does not represent a distillation of all topics taught in The Signal School.

Nonelectronic Aspects of the Training Content

In addition to electronic trouble shooting skills and knowledges established by the cue-response method, the MOS 232.1 repairman must have certain nonelectronic skills and knowledges, such as march order for the equipment, supply procedures, and antenna hydraulics. These aspects of the course were not examined in the present study. They were, however, included in the training to give students the skills required in the field should they be assigned to operational M33 units.[1] This procedure also gave the students an amount of material, extraneous to trouble shooting, to master that was comparable to the extraneous material which standard students had to learn. Standard lesson plans for these topics were used in the experimental course. These topics comprised less than 10 per cent of the total experimental course time.

Basic Electronics Instruction

A number of the topics taught the experimental group were the same as those taught in The Signal School Basic Electronics course.

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[1] At the time of graduation there were no operational M33 sites. Therefore, the experimental graduates could not be sent to the field for further testing.

These topics included nomenclature, color codes, and multimeter operation. Such topics were generally introduced in the experimental program as the students needed them to accomplish other tasks.

However, late in the training program a group of students came to the experimenters and indicated they had heard other (standard-trained) technicians talking about trouble shooting in terms they did not understand. It was their feeling that perhaps they were not being taught all they needed to know to do their job. The problem thus created made it necessary to adjust the training program to fit the man for the operational setting. This was done by giving an explanation and demonstration in the ninth week, designed to convince the students that the electronic jargon they had heard referred to things they knew by other names. Eight hours of training were needed to inform students about the unfamiliar terms and concepts. Of course it was not desired or intended to develop the concepts to the extent possible in 11 weeks of basic electronics in the Basic Electronics course.

During the special explanation, students were told that the circuits they knew as "branching circuits" were called parallel circuits in basic electronics schools. Likewise they were told that signal flow was caused by flowing electrons. Electrons were defined as small units invented by scientists to explain the voltages and wave forms the students knew as cues. All other "electronic" terms used in the basic electronics program, but not known to experimental students, were presented and defined in terms with which the student was familiar.

As far as could be determined, the explanations given during this period satisfied the experimental students. Thus, this solution answered the practical problem of how to train students so they can translate standard nomenclature and hypothetical constructs into terms with which they are familiar.

Limitations on Training Time

As the experimental students were not allowed to take any materials home with them for study, the time students were in contact with the experimental instruction could be accurately determined. No man lost training time to perform such duties as KP.

Equipment Required for Instruction

On the average, five to six students were assigned to one M33 system in the experimental program during the practical exercises. It is understood that about three standard students were assigned to one M33 system during practical exercises. As there were more students per system and fewer hours devoted to practical exercises in the experimental group, the system requirements were substantially less. The total equipment time required for the experimental program in which 24 students were trained was approximately 30 system-weeks or slightly more than one system-week per student.[1]

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[1] A complete schedule for the experimental course is presented in Appendix G.

Other equipment requirements for the experimental course included spare chassis, standard hand tools, and testing instruments. The amount of such equipment per man was no more than that required in the standard course sequence, and since the experimental course was shorter it was required for far less time.

Instructors

Two groups of instructors were used in the study—one for the standard group, another for the experimental. Different instructor groups were believed necessary to control more closely the information presented in the experimental course. A compensating disadvantage in using two groups of instructors is that they cannot be exactly equated and chance differences between them may affect the results. However, Ordnance training authorities observing the experimental course instructors regarded them as inferior to standard Ordnance instructors. Accordingly, instructor skill, as a factor favoring the experimental course, is discounted.

There are several reasons why instructors in the experimental course could not be considered as proficient as those in the standard course. The newly assigned standard course instructor would have studied the M33 system for a minimum of 30 weeks; he would also have graduated from a methods of instruction course; he would have spent additional time in specific lesson preparation before being allowed to instruct. In the experimental course, the four enlisted instructors had had only six weeks of training on the M33 radar system and no previous instructional experience. The principal instructor on electronics was a female civilian who spent 28 weeks learning the M33 system and the Army methods of instruction. In an earlier pilot study, students she taught did neither better nor worse in learning to trouble shoot the tracking radar portion of the system than did students taught by a male officer instructor.[1]

Two instructors for the experimental course, a sergeant and a civilian, had received the MOS 232.1 and had extensive experience with the M33 system, but they had had no previous experience as instructors. They taught all the nonelectronic topics, such as antenna hydraulics and march order, which were essentially unchanged from the standard course. They also taught some electronic topics, such as power supply and use of the special test equipment—Ord 6. These two men served as instructors in practical exercises, and one was sometimes present in class as an equipment repairman.

The topics, instructors, and approximate number of hours taught by each instructor are listed in Appendix H.

Training Methods in the Experimental Training Program

The objective of this study was to test the cue-response analysis which produces a certain course content. To test the course content empirically, students must be trained in the use of that content, according to some type of training method. The student's ability that is evaluated is then a joint product of the content and the training method. This confounding of factors is unavoidable in an empirical test but it need not be serious in practical terms.

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[1] See Appendix F.

In the present study it may reasonably be assumed that the factor which allowed the reduction in training time was the course content derived by the cue-response method. However, with empirical validation the training method through which this content is transmitted to students is a factor which can increase or decrease student proficiency. It cannot be assumed that the content has exactly the same effectiveness with any training method other than the one used in the study. For practical purposes this confounding is not of great importance, as the training method used in the study was consistent in principle with present Army techniques. No new "experimental" training method was intentionally introduced.

Various aspects of the training method used in the study are described in this section. The reader may judge whether the method departs from principles in use in standard Army courses. It may be expected that the principles were implemented somewhat differently with cue-response content than with standard content but this does not represent a change in principle.

Training methods are considered here in terms of several aspects of presenting cue-response content in a training program: (1) transmission medium—how information is transmitted to the students, (2) generality of classroom discussions, (3) order of presentation of materials, and (4) time allotted to each topic or aspect of training.

Transmission Medium

Information can pass to the student through the five senses; visual and auditory senses are the primary channels, with tactual, olfactory, and gustatory in minor roles. Numerous media for the transmission of information through sensory channels are available in the modern classroom. For instance, within the visual mode there are chalkboard drawings, photographs, moving pictures, television, and operational equipment, to name only a few. Each of these media has a characteristic fidelity ranging from the relative crudeness of chalkboard drawings made by the instructor to the ultimate fidelity of the equipment itself.

The principle that should be followed is to select the medium of lowest cost that will convey the necessary information with sufficient fidelity. Of course, the cost of each medium generally increases with fidelity. Consequently, every decision to use a given medium involves a trade-off of fidelity and cost. The present research was not designed to empirically investigate the trade-off function for each medium and each type of material. However, making a trade-off decision is made immeasurably easier by the fact that the cue-response method provides an indication of the required fidelity through specification of tolerance limits for each cue and response. This fact was utilized to the maximum extent in establishing the experimental training program.

In the experimental program the instructor was the primary medium for transmitting information, but he had various aids. Block diagrams were used to define the various channels and the way in which channels were divided into segments.[1] Chalkboard drawings showed the appearance of symptoms and wave forms. Energized equipment was also used to demonstrate the appearance of the cues and their tolerance limits and to give students opportunity for practicing responses. Definitions of the location of check points that bounded the channel segments were presented in a printed table. Values of voltage and resistance readings (cues) obtained at the pins of all tubes were presented in tabular form. Schematic diagrams were used as aids in teaching schematic diagram reading as well as in teaching the tracing of parts in the equipment, that is, chassis navigation. Copies of many of these aids were given to students for use in the van after they had served as teaching aids in the classroom.

It might be noted here that certain transmission media impose requirements that others do not. For instance, when the instructor wishes to discuss certain cues without pointing to them, words must be attached. The words used for this purpose are not derived from the analysis. They were selected on the basis of nomenclature currently used in the electronics area and terms which had general descriptive meaning. The story used to talk about the block diagram was developed on this basis. For instance, the cues associated with a given block might be an input voltage of 5 volts and an output voltage of 50 volts. A descriptive phrase for this box would be "amplifier," although the word "amplifier" is not derived from the analysis; it is used in electronics and also has a more general meaning. When more than one word was available for describing a function, one was chosen and used throughout the instruction.[2]

Format of Classroom Presentation

The format of training methods is certainly related to transmission media. It has been pointed out that the type of analysis developed in this study resulted in qualitative and quantitative definitions of cues and responses. These definitions were sufficiently exact to provide the basis for discrimination between alternative cues and responses and thus keep the equipment operating within tolerance limits. The cues and responses represent a very detailed breakdown of larger concepts and decision functions. When the training is conducted in these terms, the "steps" from what the student has just learned to what he is about to learn are very small.[3] This format appears to be an effective one for transmitting information, and not much translation is needed from the cue-response analysis format to the cue-response teaching format.

[1] An example of a block diagram and other lesson materials are presented in Appendix C.

[2] Near the end of the course it was seen that students would have to be given alternate terms if they were to mix with standard-trained repairmen. This point was discussed on page 22.

[3] The "small-step" approach is being used in the development of materials for "teaching machines."

The format for cue-response analysis does not leave the steps as unrelated parts. It is recognized that these parts must be brought together into the applicable larger concepts and decisions. The format for cue-response analysis is to place cue and response side by side. It also refers the cues and responses for one subtask or concept to a larger task or concept, by providing basic information on the relation of concepts and subconcepts.[1] Thus the format of the analysis is quite appropriate—guiding the small steps into larger steps as well as defining each step in definite terms.

Order of Presentation

The order in which various aspects of the training were presented was determined by logic in most instances, though occasionally by chance. The order of studying subsystems—Track, Acquisition, and Computer—was fortuitous. On the other hand, the logical time in the training sequence for teaching the use of portable instruments to obtain certain readings from the system was before such readings were to be taken and studied in class. Generally, as in this example, subsets of skills and knowledges that contribute to large sets of skills and knowledges were introduced in the training program just before the larger sets. This organization does not represent a new principle, but is an instance where an old principle was implemented in detail. Thus, the student was not merely told that various subskills were necessary for the total job by their organization, but was constantly shown, by demonstration, that each subskill fits into a larger skill which in turn fits into a still larger skill.

Generally, students were given four or five days of classroom instruction and were then taken to the equipment for as long a time to practice discrimination and association of the cues and responses. Improved learning might be achieved with shorter periods of each kind of activity—perhaps only two days of class before shifting to the laboratory.

Amount of Reliance on Supportive Documents

The decision on how much material to require the students to learn and how much to provide only in supporting documents was an important aspect. Since the over-all training time needed to present the cues and responses to students is relatively short, it was decided to require the students to memorize most of the material. This was consistent with a course that was not of the "cookbook" variety. This meant the students would memorize the patterns of cues and responses that add up to the system logic. That is, they learned all the alternative localization and sectionalization cues and responses along with the symptom patterns (cues). This allowed them to make logical decisions regarding which tests and checks (responses) to make, rather than to follow a procedure spelled out in a book. The analysis reduced the number of alternatives from which students could choose by teaching the student efficient choices rather than by listing only one choice in a book.

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[1] Appendix A includes examples of subtasks and tasks and their relationship as indicated in the format for analysis.

Homogenizing the Rate at Which Information Is Presented

Pilot studies were used to establish the approximate amount of time students required to learn each course topic. The Track subsystem was used as a vehicle in these pilot studies. A block diagram of the Track subsystem was prepared. Then small groups of students were trained to recognize the various channels and their segments on the block diagram and to describe the relations between the various cues and responses. The amount of time required for the students to absorb this information and report it back to the instructor without any major errors was recorded.[1]

On the basis of data from the pilot studies, the high information content of difficult topics was scheduled over long periods of time, thus "thinning out" the amount of information presented per unit time. Simpler topics were compressed into shorter periods of presentation. Thus the rate at which information was presented in the final program was approximately equal—that is, homogeneous—over all periods of instruction.

It might be noted that this approach is quite different than another commonly used basis for allotting training time, namely, the amount of time a man spends in doing a particular subjob in the field. The assumption inherent in this approach—that the more often a subjob is required, the more time should be spent in training—often leads to unworkable conclusions. For instance, removing tubes might require a high percentage of a repairman's time on the job but it is not a difficult task and should not consume a large portion of the repairman's training time.

The degree of learning was described as sufficient when the student needed no more specific prompting from an instructor. This means that he would know the tolerance limits of the various aspects of the system's functioning well enough to prompt himself, and would therefore know when he had succeeded in getting the system operating within tolerance limits. The student would not necessarily always take the proper course of action in correcting the malfunction on his first attempts, but he would be able to recognize that his first attempt was not correct. After a student's degree of learning was carried to the point where he could determine the error in his original reasoning and correct it, further improvement could come only with unguided practice. Such practice would gradually reduce the number of false leads the student would follow before bringing the system within tolerance limits.

The pilot studies were conducted on the Track subsystem only. The time allotments established for that subsystem were used as guide lines in the final program for the other subsystems. These time allotments obtained in the pilot studies and the major study reported here should have direct relevance for other radar systems such as Nike and Nike Improved since their subsystems are quite similar (in cue-response terms) to the M33 subsystems.

[1] The pilot studies are summarized in Appendix F.

THE TESTING PROGRAM

After graduation from their respective courses, 17 students from the standard and 20 students from the experimental group were tested on an objective, nine-day performance test. This test is one of the longest and most inclusive ever used in electronics training research. Length alone, however, does not guarantee that content and reliability will be representative. To ensure representativeness, the test required the subjects to trouble shoot for malfunctioning parts (e.g., resistors, capacitors) in as many different chassis as the average repairman would encounter during his first 8 to 12 months in the field.[1] Further, the test measured the subjects' ability to energize, adjust, and trouble shoot for individual malfunctioning parts in the electronic portions of the M33 system with both common and special test equipment. The estimate of the true ability of subjects was certainly made more reliable by having a large number of work samples from the criterion jobs in the field.

The energizing portion of the test was a partial measure of operator skills. Other portions also tested certain operator skills since manipulation of operator controls is necessary in trouble shooting. There was no complete test of operator skills because each man had to demonstrate satisfactory operator proficiency during his training period. It was clear that each man in the experimental group could operate the system during his training, and it was presumed that this was true of the standard group as well.

The Subtests

The performance test consisted of four subtests (briefly summarized in Table 3). Each subtest measured a set of skills and knowledges which

Table 3

Subtests Comprising the Performance Test

Subtest	Number of Items	Total Possible Score	Length (days)	Skills and Knowledges Measured
Warm-up	13	96	½	Energize, adjust, trouble shoot to tube level
Van	44	176	5½	Trouble shoot to replaceable part (e.g., resistor, capacitor) on energized system
Shop	30	30	2½	Trouble shoot within chassis to replaceable part with common test equipment
Ord 6	2	16	½	Trouble shoot within chassis with special test equipment Ord 6

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[1] Ralph H. Kolstoe *et al. Ordnance IFC Electronics Maintenance Personnel: Analysis of Activities With Implications for Training. Part I—M-33*, Technical Report 31, Human Resources Research Office, Alexandria, Va. (published in Washington, D.C.), December 1956.

were, to some extent, independent of the others. The student's job in each subtest was to identify the individual, throw-away parts which constituted the malfunction. Students were not required to unsolder the malfunctioning parts and replace them with new ones, as acceptable soldering skills had been demonstrated by them during training.[1]

Sample items from each of the tests are presented below:

(1) Warm-up Subtest

(a) "Your first job is to energize the radar and the computer. Do not energize the magnetrons." (Student then energizes the system.)

(b) The test administrator makes the following maladjustments while the student is out of the van:

Tracking Console PPI, offset.
Range switch to 120,000 yards.
Range circle handwheel to maximum CW.
Offset range controls on video amp. CCW to lose range circle.
Offset amp. controls, E-W demodulators, for eggshaped sweep with NS, R1 of demod. max. CW. Other max. CW.
Offset vertical balance pcts on sweep generator to more North sector off scope and give horizontal unbalance.
Throw S-1, N-S and E-W demodulator chassis to Bal.
Offset centering 3/4" 01" southeast. Throw S-1, N-S and E-W demods back to OP.
Set range handwheel at 38,000 yards.

The student is told when he starts this item:

"This PPI presentation is out of adjustment. Readjust it so that it is working properly."

The item is scored for centering, circularity, and range.

(2) Van and Shop Subtests

The task is to locate the individual, throw-away malfunctioning part.

Malfunctioning component	Time (minutes)	Student is told:
L1 open in Acq PPI video amp.	15	"You have no video on the Acq PPI."
CR4 short in Track Pulse Demod.	15	"The 100-yard notch is missing from the A scopes."
R23 open in Track Relay Amp.	15	"Something is wrong with your Acq auto slew for range."
T1 short to ground in Track IF Amp	20	"Your Track receiver is not operating properly."
K62 pin 1 open in Plot Board select Relay Panel	40	"Your present altitude board is not operating properly."
K3 open in Track RF Coupler	30	"Your Track video is very weak."
Quadrant switch spring broken in El Servo	40	"Your elevation and time readings are low."
E-12 terminating resistor open	60	"Presentation on A scopes is incorrect."

(3) Ord 6 Subtest

The student is told:

"Perform the Ord 6 check on the Pulse Synchronizer Chassis. The time limit for this check is two hours. The quicker you finish, the more points you earn. You must get

[1] The items used in the final test are still being utilized in HumRRO research. In order to maintain test security, only sample items are provided in this publication. Any agency which needs to know all items may contact the Director, HumRRO to obtain the complete set.

each check right before going to the next one. Tell me when you complete each section as indicated by the arrows." (Demonstrate and point to test equipment.)
"Now begin and tell me when you have completed the first check." [The test administrator scored the students on the form below as each check was accomplished.]

(1a)	(1b)	(2)	(3)	(4)
25N ☐	17N ☐	1500 pps ☐	25V ☐	6V ☐
0.2 ☐	0.35 ☐		Sync W/J1 ☐	5 μsec ☐
2+0.4 ☐				

In its original form the performance test contained 115 problems, or items. As experimental students had inadvertently studied 26 of these problems in practical exercises, these items were discarded from the analyses and are not included in Table 3. It is not known how many of the scored test items may have been studied by the standard course students in their practical exercises.

Subtest Scoring

For the major portion of the subtests an item consisted of a malfunction inserted in the system. No intermittent or multiple malfunctions were included. The correct solution for each item consisted of identifying the malfunctioning (replaceable) part.

In the Warm-up subtest extra points were given for rapid repair as well as for the correct identification of malfunctions, since a man who can trouble shoot faster than another is considered to be a better trouble shooter.

In the Van subtest one point was given if the chassis which contained the malfunction was identified; two points if the stage which contained the malfunction was identified; three points if the tube to which the malfunctioning part was attached was identified; four points if the malfunctioning part was identified (including identification of the tube when it alone was the defective part).

In the Shop subtest one point was given if the malfunctioning part was identified; no points were given if it was not.

In the Ord 6 subtest eight separate checks were to be made for each of the two malfunctioning parts; one point was given for each check made correctly.

Time Limits

A time limit was set for each of the items in each subtest. If the student had not finished an item in the allotted time, he was stopped and the item was scored on the basis of what he had completed. The time limits for the Van, Shop, and Ord 6 subtests were established on the basis of judgments made by expert repairmen. No effort was made to obtain highly accurate estimates, since it was desired that some items in a subtest could be finished only by a rapid worker and that others could be finished by even the slowest. (The data analysis revealed that this objective was met.)

Proportion of Malfunctions Selected for the Test

Malfunctions known to occur in field operation were selected for the test. Selections were made by a senior Philco technical representative, an M33 repairman with eight years' experience in the field, and a research man not otherwise associated with the Task who had advanced knowledge of electronics. These men were instructed to select some malfunctions that are extremely difficult to identify, some that are easy, and some of medium difficulty. The proportion of each type was not considered important as long as the entire range of easy to difficult was represented. (Data analysis indicates a wide range of item difficulty was obtained.)

The frequency of types of electronic parts that would cause the malfunctions selected for the test (e.g., tube, resistor, capacitor, crystal) was compared to the frequency of part malfunctions recorded in the field.[1] The percentage of each part type included in the test was found to match the field proportions quite well (see Table 4). Emphasis on the generally easier items (e.g., tubes) was slightly reduced so that emphasis could be placed on more difficult items (e.g., capacitors).

Table 4

Parts Replaced in Field and in Van Subtest

Parts	Percentage of Total Parts Replaced	
	Field Study[a] (499 repairs)	Van Subtest
Tubes	33	27
Resistors	20	27
Crystals	7	7
Mechanical parts	6	7
Inductors	6	7
Switches	5	4
Motors	4	0
Hydraulic gaskets	4	0
Cables and connectors	4	5
Capacitors	3	10
Networks	3	5
Fuzes	3	2
Synchros	2	0
Meters	0	0

[a] The data in this column were reported in Kolstoe *et al.*, *op. cit.*, p. 20.

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[1] Kolstoe *et al.*, *op. cit.*

The number of different chassis that had malfunctions placed in them was equal to the number of different malfunctioning chassis the average repairman would encounter during his first 8 to 12 months in the field. This does not mean that all possible malfunctions were included in the test. It does indicate that the test items represented a large proportion of the troubles the average repairman would encounter during his first enlistment.

Test Administration

The test administrators were M33 repairmen, Philco technical representatives, and Ordnance School instructors. The exact composition of the test administration group changed from time to time during the period of the study. As reassignments caused some test administrators to leave, new men were trained to take their place.

There was a test administrator for each man being examined. For each test item the administrator inserted the malfunction, started the man being tested, stopped him at the expiration of the time limit (if necessary), and recorded answers. He introduced each item with a standardized, general indication of the nature of the symptom, such as "trouble in the computor" or "can't track in range." He was not allowed to answer any questions that might be asked him or to give any indication of the location of the malfunction.

If a man desired to use chassis substitution as part of his trouble shooting method, the administrator provided chassis information. Rather than physically exchange a chassis from the equipment for one from the Ord 7 load of spare chassis, the test administrator would tell the man what the results of that exchange would be and charge him two minutes for the information. This penalty was selected as the average amount of time that an actual exchange of chassis would have required.

The test administrator was responsible for the safety of the man being tested and for the equipment.

Test Security

Test administrators when interviewed were sure that there were no breaks in test security in either the standard or experimental groups. Their opinion is a good indicator of security because they were in a position to see when a student solved a problem without making appropriate tests in the channels, segments, and areas associated with the malfunction.

Chapter 3

RESULTS OF THE VALIDATION STUDY

GENERAL FINDINGS

Although the experimental course required 60 per cent less training time than the standard course, there were no significant differences in proficiency between the two groups after training was completed.

When all subtest scores are added together, unweighted, the results are as presented in Figure 3.[1] The difference between mean test scores of the standard and the experimental groups is of no practical or statistical significance. The standard deviation of performance scores is 11.7 for the standard group and 9.2 for the experimental group.

Training Time and Performance Comparison

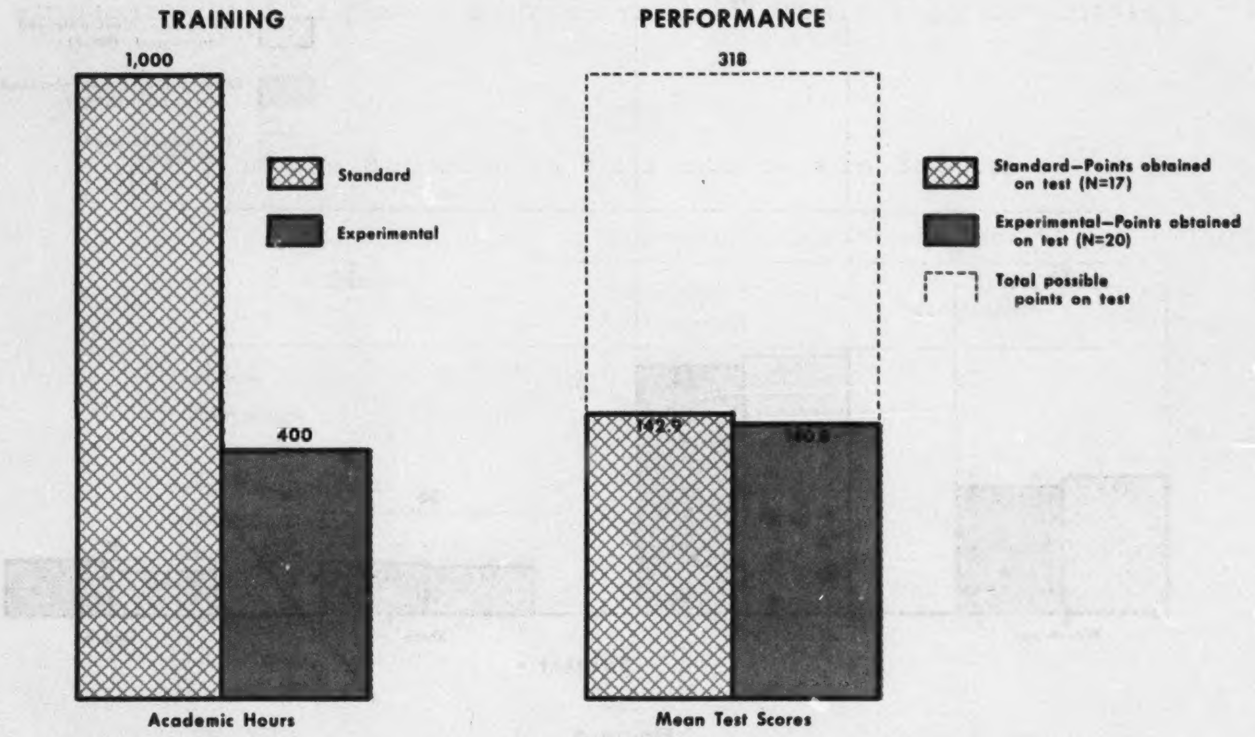

Figure 3

It should be noted that the maximum possible score of 318 does not represent the score an experienced repairman would make. The difficulty of the test was adjusted so that even experienced repairmen could

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[1] The four experimental and four standard students who failed to graduate have been eliminated from this and all subsequent analyses.

not obtain a perfect score. A test score that is 50 per cent of the total possible score should not be interpreted to mean that exactly 50 per cent of the field problems will be solved by a man obtaining that score on the test. Rather, the test is so designed that a man with a higher score can be expected to perform better in the field than a man with a lower score, but it is not possible to indicate exactly how much better.

DETAILED FINDINGS

The results are further described by subtest, subsystem, and accuracy of trouble shooting.

Subtest Scores

Mean scores for the two groups were about equal on each subtest of the performance test.[1] None of the differences is large enough to be a practical indication of the superiority of either group. The average scores for the subtests were generally less than half of the total

Mean Performance Scores on Subtests

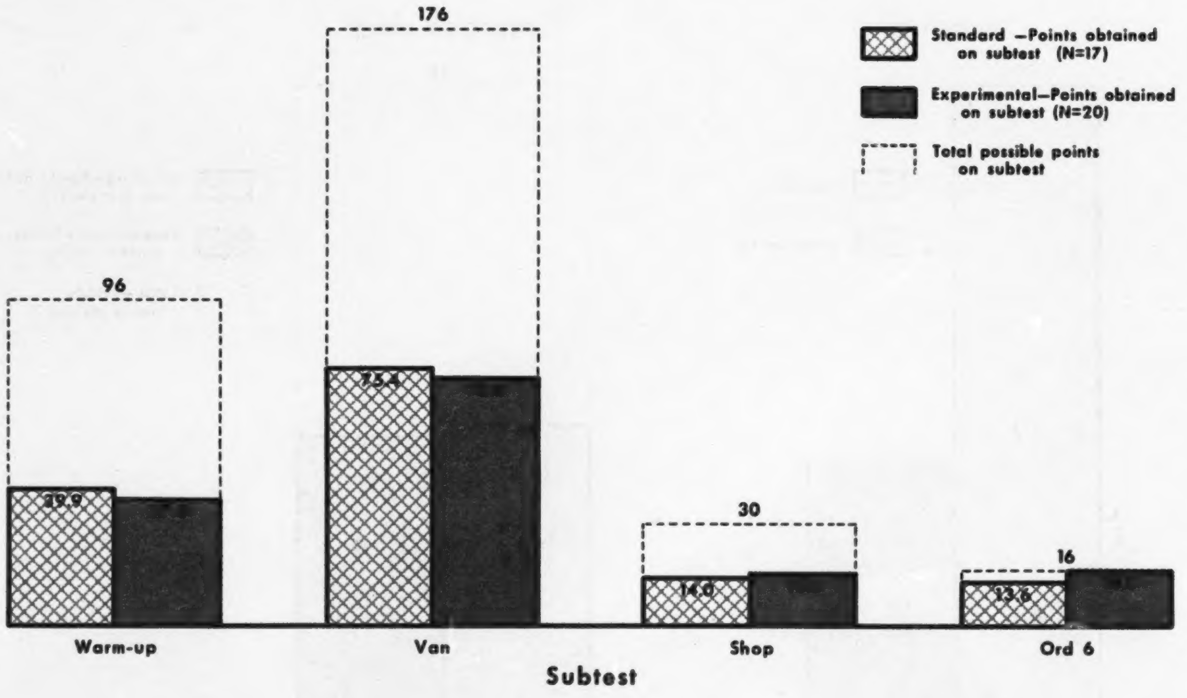

Figure 4

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[1] An appropriate method for estimating the reliability of this test is the test-retest method. The Spearman-Brown split-half method is not as appropriate because the job, and consequently the test, is not homogeneous. That is, a student may reasonably be expected to vary in proficiency in different aspects of the job and test. To the extent that this is true, a split-half measurement will be an underestimation of the true test reliability. The split-half correlation is provided here because the cost of obtaining a test-retest estimate is prohibitive. The Spearman-Brown split-half (with correction for double length) index of reliability of the test is .70.

possible scores, as can be seen in Figure 4. An exception was the Ord 6 test on which the experimental group obtained the total possible score and the standard group's score was only slightly less.

Subsystem Scores

In the Van and Shop subtests the two groups did not do equally well on the three M33 subsystems, although there were no differences of practical importance. (See Table 5.) The experimental group obtained the greater percentage of their total score in solving Acquisition and Track subsystem problems, but a smaller percentage in the Computer subsystem problems than did the standard group. The standard group did equally well in all subsystems.

Table 5

Percentage of Groups' Total Scores Obtained in Each Subsystem

Group	Track	Acquisition	Computer	Total
Standard	32	34	34	100
Experimental	37	37	26	100

The comparative lack of proficiency of experimental students on the Computer subsystem may have been due to the fact that the initial Computer analysis was not properly conceived. It was not recognized at first that, to a considerable degree, an operator type of analysis was appropriate for use in maintenance of the Computer subsystem. The maintenance method of analysis was used first, and much of the final training program was based on this analysis. It was only after Computer training had begun that the operator analysis appeared more appropriate and was substituted. This may have produced student confusion which might have depressed performance.

There was only a slight tendency for individual men to maintain the same relative rank with respect to the other men in each of the three subsystems.

Accuracy of Trouble Shooting

As discussed in Chapter 2, the scoring system for the Van subtest rewarded the trouble shooter for degree of accuracy. One point was awarded for the identification of the chassis containing the malfunction; two points for the identification of the stage containing the malfunction; three points for the identification of the tube to which the malfunctioning part was attached; four points for the identification of the replaceable malfunctioning part.

The results presented in Table 6 indicate that total scores for the two groups were obtained in essentially the same manner. The percentage of points received at each of the four degrees of accuracy is remarkably similar in the two groups.

Table 6

Percentage of Groups' Total Scores Obtained
by Isolation of Trouble to Equipment Area

Group	Chassis	Stage	Tube	Part	Total
Standard	18	5	13	64	100
Experimental	16	6	8	70	100

Performance on Difficult Items

It might be hypothesized that one group would be able to solve difficult problems more readily than the other. The test included difficult items in order to provide data on this question. Performance scores on the most difficult items in the test are given for the two groups in Table 7. Items classed as difficult were those on which almost no students in either group scored any points; the total scores of the two groups were lowest on three of the items presented in the table. Three of the easiest items are also presented for comparison purposes.

Table 7

Comparison of Scores Obtained
on the Most Difficult and the Easiest Items

Item	Time Limit (minutes)	Group's Mean Performance Score*	
		Standard Group	Experimental Group
Most Difficult			
C6 open in Comp XR LPSA	13	0.3	0.1
V2 bad in Acq L.O. power supply	30	0.3	0.6
R41 open in Comp Modulator	17	0.5	0.6
Easiest			
V4 bad in Pulse Sync	20	2.8	3.3
V1 bad in DC Amp	10	3.5	2.9
V7 pin 1 short to pin 2 in Track AFC	25	2.8	3.8

*The best possible score on each item was 4.0.

It can be seen that the difficult items were about equally hard for both groups. Neither training program provided students with a well-developed ability to solve these problems. This does not mean that both groups scored equally well on items throughout the test. On some items the experimental students scored low and the standard students high; on other items the reverse was true.

OBSERVATIONS OF BEHAVIOR DURING THE TEST

The students of both groups were observed on various occasions during the testing program, and no systematic differences in the trouble shooting behaviors were noted.

The test administrators watched carefully for unsafe behaviors. Only a few questionable practices were observed, and these were seen equally often in both groups.

It was noted that in some instances the experimentally trained students used chassis substitution more than the conventionally trained students. When this occurred, it was usually on an extremely difficult problem. Where the standard student might give up after failing to identify a malfunction by other methods, the experimentally trained student might try chassis substitution. The use of this entirely reasonable procedure did not appreciably affect the score of either group, as evidenced by the fact that both groups received about the same percentage of their total score for identifying chassis stages, tubes, and parts.

Why didn't chassis substitution improve scores more? It may be that other methods failed because students misread symptoms and were "way off the track." The chassis substituted were similarly "way off the track."

SUMMARY OF RESULTS

The results provide statistics regarding the effectiveness and economy of the cue-response methods. Generally, they indicate that the methods produced a content for a training program that was no less effective than the parallel standard program and was certainly more economical of training time and equipment. Actually students learned the experimental content in less than half the time required for conduct of the conventional course.

The cue-response methods were designed to provide economical and effective training, and they succeeded for the M33 system. The methods were also designed to be both general and forecasting in nature, but the present program did not include tests of these characteristics. Such tests will be made before research recommendations regarding broader implementation are made.

APPENDICES

Appendix A

CUE-RESPONSE ANALYSIS (OPERATOR)

This appendix contains two examples of cue-response analysis. The first is a lesson plan based on analysis of the M33 operator task in this study. The format of the cues and responses in this lesson plan has been changed from that in which the analysis was made. Because many readers will be unfamiliar with the M33 operator task and will have no opportunity to inspect the M33 equipment, a second analysis is included for a more accessible item of equipment—an office mimeograph machine. For this example, a complete cue-response analysis of an A.B. Dick mimeograph operator's task is presented. The principles of analysis and cue-response format are the same for this machine as for the most complex electronic system.

LESSON PLAN BASED ON TASK ANALYSIS OF THE M33 OPERATOR TASK

LESSON PLAN

INSTRUCTIONAL UNIT: OPERATOR TRAINING.

TYPE: Conference, demonstration and practical exercise.

TIME ALLOTTED: Three and one-half (3 1/2) hours.

CLASS PRESENTED TO: Class as designated.

TOOLS, EQUIPMENT, AND MATERIALS: One (1) ea operational M33 system.
One (1) ea chalkboard, w/chalk.

PERSONNEL: One Hvy FCS Repairman.

INSTRUCTIONAL AIDS: None

REFERENCES: None

STUDENT ASSIGNMENTS: None

STUDENT UNIFORM AND EQUIPMENT: Uniform; as designated.

TROOP REQUIREMENTS: None

TRANSPORTATION REQUIREMENTS: None

NOTE: Prior to the presentation of this unit of instruction the instructor should prepare on his chalkboard a sketch of the PPI scope (planned position indicator) with all characteristic lines, the PI (precision indicator), and the A scopes in all modes of operation (i.e., NORMAL, OFF, and SELECTED signal).

1. PRESENTATION. (Conference and demonstration, 30 minutes)
   a. Introduction. (Five minutes)
      (1) Objective. The objective of this period of instruction is to teach the student how to operate the M33 Fire Control System.

(2) Standards. It is expected that at the conclusion of this three and one-half hour period of instruction all of the students in the class will be capable of properly energizing and de-energizing the entire M33 Fire Control System and performing all of the operator jobs on this system.

(3) Reasons. As potential and future M33 repairmen, the students must know and understand the problems and techniques involved in the proper operation of this set. Many of the trouble shooting procedures depend on knowledge of the effect of operator controls.

b. Explanation and demonstration. (45 minutes)

(1) Instructor points out and simulates the energizing of the equipment.

NOTE: Instructor should proceed to the equipment accompanied by the students for a simulated energizing of the system.

(a) All energizing adjustments are made on the main power panel.

(b) Instructor should go through, in sequence, the energizing of the system.

(1) Make line voltage checks. Needle should indicate 120 volts in the C position of the indicator knob. In the B and A positions, it should read 120 volts ± 5 volts. If these meter readings are not obtained, simply twist the adjusting dial until 120 volts is indicated on the meter.

(2) Check the control drawer to see that all the Man-Aid-Auto switches are in the Main position and that the acquisition scan switch is OFF.

(3) Turn main power switch to ON position.

(4) Turn radar power switch to ON position.

(5) Turn ON: the personnel ventilation switch, acquisition power switch, track filament switch.

NOTE: Wait until low volts lamp (yellow lamp) turns on (15 seconds after the radar power switch is turned ON). THEN:

(6) Turn low volts switch to ON position. Do not move the switch labeled BY PASS.

(7) Make voltage check—turn voltage check knob slowly clockwise. In the first 16 positions the indicator needle should indicate within the right quarter of the meter, the next two positions should give meter readings in the center quarter of the meter, and the last knob position should give a meter reading in the left quarter of the meter. Then turn the voltage check knob to the OFF position.

(8) Turn Indicator High Volts switch to ON position.

(9) Turn Track Scanner to ON position.

(10) Turn Excitation switch to ON position.

(11) Turn on high power servo (wait for Track and Acq High Voltage (yellow) lights to come on), then, starting with the track high voltage, push the ON button (red light should light). Then turn the Track Min-Max adjusting knob until the meter needle reads about 60 (or 6); then push the HV SUPPLY switch UP, the meter reading should go down to 40. Then push the selector switch up and the needle should go down a little; push the selector switch down and the needle should go up a little. These meter readings obtained by moving the selector supply switch should NOT be extreme. Repeat the above operations for the Acq system on which the Acq meter reading should be 40 rather than 60.

(12) Turn up the intensities for the three A scopes, the PPI, and PI on the Tracking Console. Turn up the intensity for the PPI and PI on the Tactical Control Console. Turn the acquisition scan azimuth knob to either one, two, or three (that is 10, 20, or 30 revolutions per minute). This starts the acquisition antenna to rotate.

NOTE: De-energizing of the system is the reverse of energizing. The operator should be careful to turn the Min-Max knobs completely counterclockwise to OFF before pushing the OFF button.

NOTE: While waiting for the system to warm up before completely energizing the set, move the chalkboard and explain the PPI, the PI, and the A scopes. The PPI scope should be explained complete with sweep, steerable azimuth line, range circle, track azimuth line and the track range circle. Be sure to explain that the steerable azimuth line and the range circle are used by the acquisition operator on his PPI scope, to designate a target. Be sure to emphasize the location and importance of the electronic cross (it shows the position of the tracking antenna in range and azimuth only).

(1) Diagram and explain the PI (precision indicator). (Explain that it shows an enlarged view of a small portion of the PPI scope.) Draw a small square simulating a target appearance on the PI.

(2) Explain the A scopes. Show what we refer to as the sweep, the 500 yard expanded sweep, and the 100 yard notch. Show how the sweep is topped with what we call grass; show how a target echo will appear on the A scopes in the OFF, NORMAL, and SELECTED signal modes of operation. Explain that under certain conditions it is desirable to use the NORMAL and SELECTED signal and thus accomplish more exact tracking by using the two target echos and matching those target echos as nearly as possible on the face of the scopes.

NOTE: When the system has completely warmed up, complete the energizing of the set and show the operator tasks by demonstration. Have the students perform the operator tasks in practical exercise.

2. APPLICATION

a. The tracking operators put their scopes in the OFF position and adjust the intensity and focus of their scopes. The PI is placed in the track position.

b. The acquisition operator selects targets from the screen of his PPI scope and designates them by laying the steerable azimuth line and the range circle on the image of the target and pressing the designate button twice.

c. The target is tracked in the following manner: The tracking azimuth operator pushes the acquisition switch, which slews the tracking antenna towards the target. When the range indicator dial begins to settle he releases the acquisition switch and checks the PI scope for the target. If he finds the target on the PI scope he announces "Identified." (The acquisition operator may then search for and designate other targets.) Simultaneously the track azimuth operator and the track range operator line up the target echo on the PI scope with their manual controls. At the same time they are constantly and habitually checking their A scopes for the presence of a target echo. When the target echo is lined up with the cross on the PI scope the track range operator announces "Search," whereupon the track elevation operator searches in elevation until he has the target on his scope. When the target appears, he announces "Target." When the target is in the range notch on all three scopes the range operator announces "Auto." All operators at that time turn their operator switches to the AUTO position and the azimuth operator pushes the tracking button which indicates to the acquisition operator that the tracking operators have acquired and locked-on to their target.

d. To end tracking the acquisition operator pushes the CEASE TRACKING button and all tracking operators thereupon return their respective control switches to the manual position.

NOTE: The instructor should show how to track in AIDED. He should also insure that all students have opportunity to become familiar with all modes of scope operation, OFF, NORMAL and SELECTED signal.

NOTE: When students become proficient at any operator task they should be rotated among the different acquisition and tracking operator tasks as long as time permits to develop proficiency in these tasks for motivation as well as for familiarization.

3. REVIEW. (10 minutes)

a. The instructor should summarize by asking the students questions.

b. The instructor should review and conclude this class by re-emphasizing the importance of the M33 to our strategic defense. He should remind the class that the range of the M33 is 120,000 yards, that the system does its job by sending out waves much like a TV broadcasting antenna, these waves striking aircraft flying within the range of the radar, and bouncing back to the system to become represented on these scopes. The instructor should point out that in a relatively short time the students have achieved a familiarization with the M33 and with the operator tasks involved in operating the M33. This familiarization will be beneficial in the students' future work on the M33 system.

TASK ANALYSIS OF MIMEOGRAPH MACHINE
(A.B. Dick No. 445)

The task is presented first in terms of a gross analysis and then in terms of a subtask analysis.

GROSS TASK ANALYSIS

Name of Task	Display or Cue	Critical Values	Response	Subtasks (By Number)
A. "Set Up" Before Run	Position of brake	Not in 9 o'clock position	Move to 9 o'clock position	1
	Recall of last inking	Copy light since last inking	Measure ink	17, 18
	Amount of ink on stick after measuring	Less than 1/2 inch	Add ink	19, 20
		More than 1/2 inch	Needn't add ink	20
	Width of paper to be used	Different than previous paper	Change rail and guide	7, 21, 23, 11
	Length of paper to be used	Different than previous paper	Change breaker bar	7, 22, 24, 11
	Weight of paper to be used	Different than previous paper (Normal weight equals 20 lb.) The normal control positions for 20 lb. are: (a) Feed grip at second notch from top	Increase for less than 20 lb. paper	25
			Decrease for more than 20 lb. paper	26
		(b) Buckle at middle number	Increase for less than 20 lb. paper	29
			Decrease for more than 20 lb. paper	30
	Amount of paper in machine	Less than one inch	Add paper	7, 10, 11
	Proposed speed	Feed pressure at second ring for speeds up to 100 copies per minute	Increase for higher speeds	27
			Decrease for lower speeds	28
	Desired speed	Increase over previous run	Increase	32
		Decrease under previous run	Decrease	33

(Continued)

Name of Task	Display or Cue	Critical Values	Response	Subtasks (By Number)
B. "Set Up" Before Each Different Stencil Run	Cover on cylinder or not	Cover on	Remove cover	9
		Cover off	Attach stencil	2
	Number on counter	Not correct	Set correct number	3
	Machine on or off	Off	Start	35
C. Any Time During Run	Print with respect to: (a) Top of page	Too close	Lower print	4, 12, 35
	(b) Side of page	Too close	Move from side	4, 13, 35
	(c) Horizontal of page	Diagonal	Straighten	4, 14, 35
	(a), (b) or (c)	Print off page	Use "ink up" procedure	4, 15, 35
	Lightness of print (a) Ink not previously distributed	Print too light	Distribute ink	4, 16, 35
	(b) Ink previously distributed	Print too light	Add ink	4, 19, 20, 35
	Speed of machine		Changes speed	32 or 33
	Amount of paper	Less than one inch	Add paper	4, 7, 10, 11, 35
	Dirt on paper (a) Sides	Office standards	Clean retainer pads	4, 31, 35
	(b) Center	Office standards	Clean feed roll	4, 34, 35
D. End of Each Different Copy	Counter bell rings		"End off" procedure	4, 5, 6, 7, 8, 9

ANALYSIS OF SUBTASKS
(Cue Elements Are Identical to Control Elements in Subtask)

Name of Subtask	Control	Control Action (Response)	Indication of Response Adequacy
1. Release Brake	Brake	Turn clockwise up	Brake stop in 9 o'clock position
2. Attaching Stencil	Wheel	Turn	Stencil head clamp available
	Stencil head clamp	Lift left end	Stencil head clamp loosens
	Release latch	Lift	Stencil head clamp loosens further
	Stencil head clamp (edge away from stencil)	Push down	Stencil head clamp comes open
	Stencil	Put under head clamp as far as it will go (face down)	Feels it is against "end" of clamp
	Stencil head clamp lever	Push down	Stencil secured and straight
	Stencil back	Pull backward	Torn off backing
	Stencil	Smooth around cylinder	No wrinkles on stencil
	Wheel	Turn counterclockwise (left hand)	End clamp up
	End clamp lever	Lift	End clamp opens
	Stencil	Push under clamp	Under clamps smoothly
	End clamp	Push	Holds stencil firmly
	End clamp lever	Push down	Clamp flush—stencil secured
	Wheel	Turn clockwise	"Stop here" matched, on cylinder and frame
3. Setting Counter	Recorder control knob	Lift up	Stops
	Counter	Set to appropriate number copies	Correct number
	Recorder control knob	Push down	
4. Stop	Feed control lever	Press down	Paper stops going through
	Motor switch	Turn to left	Machine stops
5. "Stop Here" Match	Wheel	Turn	"Stop here" matched
6. Remove Copy	Copy	Pick up and transfer (both hands)	Copy removed to table
7. Lower Feed Table	Feed table release knob	Push to left	Feed table goes down
8. Single Copy or File Folder	File folder or single copy	Push folder in above paper positioning plate	Stops against insides of machine
	Wheel	Turn	Folder out other side
	File folder	Remove from other side	

(Continued)

Name of Subtask	Control	Control Action (Response)	Indication of Response Adequacy
9. Removing Stencil or Cover	End clamp lever	Lift	Clamp open
	Stencil	Take from under clamp and hold up (left hand)	Stencil out
	Wheel	Turn clockwise	
	Head clamp lever	Lift (right hand)	
	Stencil	Pull from beneath clamp and place in file folder	
10. Adding Paper	Wheel	Turn	"Stop heres" matched
	Any Order		
	Quick set lever	Turn clockwise	Rails and retainers move away
	Retainer pads	Push into their housings (two)	Clicks into place
	Feed table release knob	Push to left	Table goes down
	1/2 pack paper	Fan paper and push up to paper positioning plate and register edges by slapping	Paper registered on each side and against plate
	Quick set lever	Turn to right	Paper against retainers
	Simultaneously		
	Paper	Push down paper (toward table top) between retainer pads	
	Retainer pad release pad	Push down (both sides)	Paper retains "bend"
11. Raise Feed Table	Feed table elevating knob	Turn counterclockwise	Top of pack above positioning plate below feed roll
	Feed table release knob	Push to right	Table stays up
12. Correction for Print Too Close to Top	Raise lower copy lever	Lift	Up from cylinder
	Cylinder	Move so pointer is farther from zero by the desired change in copy distance in the direction of the word indicating desired direction of print movement	
	Raise lower copy lever	Push down	Flush with cylinder
13. Correction for Print Too Close to Side	Lateral cylinder control	Clockwise to move print to right; counterclockwise to move left	

(Continued)

Name of Subtask	Control	Control Action (Response)	Indication of Response Adequacy
14. Correction for Print Diagonal Across Page	Copy leveler	Turn toward "raise" to raise right side of print to horizontal; toward lower to lower same to horizontal	
15. Ink Up	Tinsel bracket	Slide out, then lift and transport	
	Impression roller lock lever	Lift	Feel of lever striking against roller inside
	Impression roller	Pull straight out and clean (with Kleenex or Johnny paper)	No slippery spots on roller
	Cylinder and stencil and cleaner	Clean	No ink visible
	Impression roller	Place right roller bearing in its socket in machine and slide other end of roller into other side	Roller does not fall out
	Impression roller lock lever	Push down	Click and holds roller
	Tinsel bracket	Place bolt on bottom through hole and slide forward	Tinsel bracket is rigid
16. Distributing Ink	Motor switch	Turn to left	Motor and machine stop
	Wheel	Turn	Match "stop heres"
	Ink reservoir control knob	Turn clockwise	Until it is stopped
	Wheel	Turn counterclockwise (slowly), stop at "stop here" position	
	Ink reservoir control knob	Turn counterclockwise	Until it stops (straight up)
17. Remove Cap	Ink hole cap	Counterclockwise to remove	
18. Measure Ink	Ink measuring rod	Insert in ink hole as far as it will go; remove and look at it	
19. Add Ink	Can of ink	Pour ink through ink hole (1/2 can originally)	
20. Replace Cap	Ink hole cap	Clockwise on ink hole to close	
21. Set Retainer Rails	Left retainer locking thumb nut	Turn counterclockwise	Loosens
	Left retainer rail knob	Turn	Scale indicator on zero
	Left retainer locking thumb nut	Turn clockwise	Tightens
	Right retainer locking thumb nut	Turn counterclockwise	Loosens

(Continued)

Name of Subtask	Control	Control Action (Response)	Indication of Response Adequacy
21. Set Retainer Rails (Cont.)	Right retainer rail knob	Turn counterclockwise	Rail strikes a stop
	Retainer release latches	Push	Loosens retainers
	Retainer assemblies	Move both	1/2 inch in front of breaker
	Retainer clamp plate	Lift up and push	Clicks and tightens retainers
	Retainer pads	Push into housings	Clicks and remains in housing
	Stack of paper (about two inches)	Place on table against left retainer and positioning plate	Against retainer and plate and registered
	Right retaining rail knob	Turn clockwise	Retainer pad housing about 1/16 inch from paper
	Right retainer locking thumb nut	Turn clockwise	Tightens
	Retainer pad release latches	Push	Pads tightly against paper
	Paper	Wiggle and pull	Paper tight—not easily picked out
22. Set Breaker Bar	Breaker bar	Insert through openings in retainer rails or brackets so bar is one inch from end of paper when paper is against positioning plate (lower bracket hole for short paper)	Remains in place
23. Setting Guides	Knurled locking knob	Clockwise	Loosens
	Left side guide knob	Turn	Guide moves away from center
	Sheet of paper	Push in feeding slot above positioning plate	Paper does not fall out
	Wheel	Turn counterclockwise a little	Paper still gripped but out other end
	Right guide lock	Turn counterclockwise	Loosens
	Right side guide knob	Turn	Guide about 1/8 inch from paper
	Right guide lock	Turn clockwise	Tightens
	Wheel	Turn counterclockwise	"Stop here" at 11 o'clock position
	Left side guide knob	Turn	Until guide pushes paper over to other guide—but does not bend paper
	Knurled lock knob	Turn counterclockwise	Tightens

(Continued)

Name of Subtask	Control	Control Action (Response)	Indication of Response Adequacy
24. Adjust Front Stops	Front stops release knobs	Turn counterclockwise	Loosens
	Front stops	Push forward	Push paper up to tinsel bracket
	Front stops release knobs	Turn clockwise	Tightens
25. Increase Pull Power	Feed grip control lever	Down to increase	Clicks into place
26. Decrease Pull Power	Feed grip control lever	Up to decrease	Clicks into place
27. Increase Feed Roll Pressure	Feed pressure control	Clockwise to increase	
28. Decrease Feed Roll Pressure	Feed pressure control	Counterclockwise to decrease	
29. Increase Buckle	Buckle control knob	Clockwise to increase	
30. Decrease Buckle	Buckle control knob	Counterclockwise to decrease	
31. Cleaning Pads	Retainer release latch	Press and lift assembly	Assembly comes off rail
	Retainer pads	Push from assembly	Pad out
	Pads and damp cloth	Clean pads	
	Retainer pads	Push back in assembly	
	Retainer assemblies	Place back on rail	Same position as removed from clicks and secures assemblies
	Retainer clamps	Lift and push into assemblies	
32. Increase Speed	Speed control	Push to left	Clicks into notches
33. Decrease Speed	Speed control	Push to right	Clicks into notches
34. Clean Feed Roll	Left end feed roll shaft	Press	Shaft comes out right end
	Right end feed roll shaft	Pull	Shaft comes out right end
	Feed roll	Clean	Clean
	Feed roll	Insert with gear to left	Feed roll hub lined up with holes in side support brackets
	Feed roll shaft	Push to insert from right side	Clicks into place
35. Starting Machine	Motor switch	Turn to right	Motor hums and vibrates
	Feed control lever	Lift	Paper goes through

Appendix B

RULES FOR THE STRUCTURED CUE-RESPONSE METHOD OF ANALYSIS FOR ELECTRONIC SYSTEM MAINTENANCE

The following rules of analysis represent an attempt to codify the procedure developed and used in this research. It is not assumed that any person will be able to use them without instruction and demonstrations regarding the operations indicated by the rules. The amount of instruction and demonstration necessary for complete understanding is not known. The results of future research will provide additional data for answering the question.

Step 1

Select perceptible displays (visual or auditory signals on built-in indicators, such as meters and scopes) which change when malfunctions occur in the system and which may be readily discriminated from each other and from their own malfunctioning condition.

Establish the signal flow from the various signal generators to each of the selected perceptible signals; this flow must contain all the operational controls, such as switches and relays. This step provides the basis for making a signal-flow diagram of the system—for example, a set of system channels.

Step 2

Segment the channels into Gray Boxes. The Gray Boxes should have the following characteristics:

a. The inputs and outputs of each box must be definable in perceptible terms and depicted in visual form, such as a wave form or a voltage.
b. The points at which inputs and outputs can be measured should be defined (e.g., pin 5 of tube 6). These check points should be readily accessible in the system and measurable with common test equipment (multimeter or oscilloscope).
c. Gray Boxes should include about two to five tubes and parts attached to the tubes.
d. The parts included in a given Gray Box all must be capable of causing the output of that Gray Box to malfunction in a discriminable manner. (No part in a given box should cause an output from a Gray Box previous to it—a box closer to the signal generator—to malfunction.) The parts in a Gray Box may be listed by outlining the parts on a schematic diagram.

⑧

After the Gray Boxes are defined, construct a block diagram of the system, giving each Gray Box a name consistent with its function. The lines connecting the Gray Boxes will start at signal generators, pass through Gray Boxes in the various channels and terminate on a portion of the system that makes the signal perceptible (e.g., scope, meter).

A "story" should be prepared which describes the function of each Gray Box in a few words and relates each box to the boxes to which its signal(s) is sent. The story should be in terms of "single-function" Gray Boxes. For instance, an unblanking circuit may unblank for several reasons (different inputs) but its function should still be described in the singular, that is, to unblank.

Step 3

Develop a table listing the normal DC resistance values which are read on each pin of each tube in each Gray Box.

Step 4

List the normal DC resistance values of each part in each Gray Box. This information may be printed on the schematic diagrams of the system.

Appendix C

SAMPLE LESSON MATERIALS

As examples of the approach used in the experimental course, sample cue-response (maintenance) materials from one of the M33 subsystems, the Tracking Radar, are presented in this appendix. The materials specific to the other two subsystems (Acquisition Radar and Computer) are of the same type. In addition to the cue-response lesson plans and material included here, there were lesson plans for subtopics such as soldering, hand tools, and meter reading. These are general to all subsystems and did not differ greatly from standard instruction in the same topics.

The items reproduced in this appendix are a block diagram for the Track subsystem, two lesson plans, and a list of Gray Box check points. These items, when used together with TM 9-6092-3-1 and TM 9-6092-3-2,[1] define the cues and responses needed to trouble shoot the represented portion of the Track subsystem. The use made of these materials in training the man to trouble shoot is indicated in Figure 2 on page 13.

The block diagram is one form of the definition of channels and channel segments. Another form is the story (lesson plan). Each gives the same information in different format, but both are based on the same analysis.

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[1] Department of the Army Technical Manuals: TM 9-6092-3-1, *Antiaircraft Fire Control Systems M33C and M33D; Schematic Diagrams*, 16 Oct 56, and TM 9-6092-3-2 ______; *Voltage and Resistance Charts*, 9 Jan 57.

LESSON PLAN

INSTRUCTIONAL UNIT: STORY.

TYPE: Conference.

TIME ALLOTTED: Fifteen (15) hours.

CLASS PRESENTED TO: Class as designated.

TOOLS, EQUIPMENT, AND MATERIALS: One (1) ea Slide Projector w/screen.
One (1) lined and one unlined Block Diagram per student and instructor.

PERSONNEL: None

INSTRUCTIONAL AIDS: Slide (transparent) of Block Diagram.

REFERENCES: None

STUDY ASSIGNMENTS: None

STUDENT UNIFORM AND EQUIPMENT: Uniform; as designated.
Equipment; None.

TROOP REQUIREMENTS: None

TRANSPORTATION REQUIREMENTS: None

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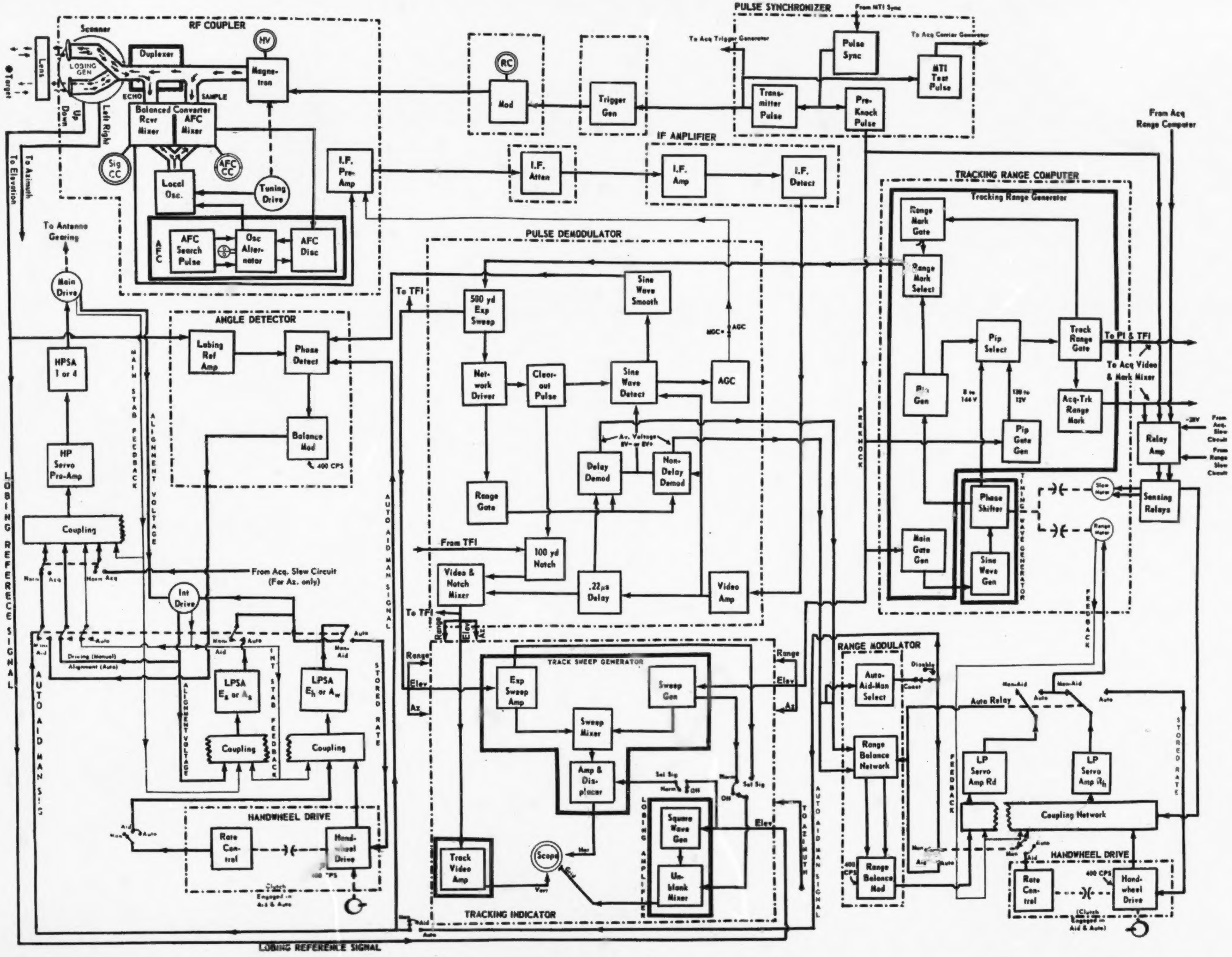
1. PRESENTATION.
   a. Introduction. (Conference, two minutes.)
      (1) Objective. The objective of this block of instruction is to have the students acquire familiarization with the general theory of how the Track subsystem of the M33 operates.
      (2) Standards. It is contemplated that, at the conclusion of this block of instruction, the student will understand the sequence of signal flow and the nature of component functioning within the track portion of the M33.
      (3) Reasons. All repairmen must be familiar with the signal flow between and functioning of areas of the Track subsystem in order to perform trouble shooting and repair on this equipment.
   b. Explanation. (Conference, eight hours.)
      (1) General.
         (a) The direction of signal flow in this Block Diagram is shown by arrow heads.
         (b) Description of Signal. The signals referred to in this Block Diagram are of many types, for example, pulse signals, gate signals, sine waves, target echoes, and DC voltage.

         NOTE: Instructor should depict these signals on the chalkboard for the students.

         (c) Size of Gray Boxes. The Gray Boxes discussed in this block of instruction may contain a single tube or several tubes. The tubes perform the functions which give the Gray Boxes their names. The Gray Box designation or name for a tube or group of tubes is for convenience and will describe a tube or group of tubes that performs a necessary function within the system.
         (d) Functions of Gray Boxes. The functions of the different Gray Boxes will fall largely within the categories of generating signals, delaying signals, amplifying signals, comparing different signals, mixing signals, shaping signals, and relaying signals. Any other function performed by Gray Boxes will be variations of the above. Any Gray Box may perform more than one function but this is the exception rather than the rule.
         (e) The signal flow within the system is generally over wires, which are depicted by solid lines between Gray Boxes. Signal flow may be radio frequency signals in one portion of the system, DC voltages in another, video in another and so forth. Any change in type of signal flow will be accomplished by a Gray Box. Mechanical connections are depicted by a dashed (· — ·) line that means there is a mechanical linkage between the components so connected. You will notice that as lines move through the system there are slight humps in some lines as they cross other lines. This merely indicates that the lines do not connect at that point. Straight line connections indicate junctions of the wires represented by those lines.


RF COUPLER
Scanner
LOBING GEN
Lens
Target
Duplexer
HV
Magne-tron
ECHO
SAMPLE
Balanced Converter
Rcvr Mixer
AFC Mixer
Sig CC
AFC CC
Local Osc.
Tuning Drive
AFC
AFC Search Pulse
Osc Alter-nator
AFC Disc
I.F. Pre-Amp
Up Down
Left Right
To Azimuth
To Elevation
To Antenna Gearing
Main Drive
HPSA 1 or 4
HP Servo Pre-Amp
Coupling
RC
Mod
Trigger Gen
I.F. Atten
IF AMPLIFIER
I.F. Amp
I.F. Detect
PULSE SYNCHRONIZER
From MTI Sync
To Acq Trigger Generator
To Acq Carrier Generator
Pulse Sync
MTI Test Pulse
Trans-mitter Pulse
Pre-Knock Pulse
From Acq Range Computer
ANGLE DETECTOR
Lobing Ref Amp
Phase Detect
Balance Mod
400 CPS
MAIN STAB FEEDBACK
ALIGNMENT VOLTAGE
AUTO AID MAN SIGNAL
LOBING REFERENCE SIGNAL
From Acq. Slew Circuit (For Az. only)
Norm Acq
Int Drive
Auto
Man Aid
Driving (Manual)
Alignment (Auto)
LPSA E_s or A_s
LPSA E_h or A_w
INT STAB FEEDBACK
STORED RATE
HANDWHEEL DRIVE
Rate Con-trol
Hand-wheel Drive
400 CPS
Clutch Engaged in Aid & Auto
PULSE DEMODULATOR
To TFI
500 yd Exp Sweep
Net-work Driver
Clear-out Pulse
Sine Wave Detect
Sine Wave Smooth
AGC
MGC
Av. Voltage 8V+ 8V+
Delay Demod
Non-Delay Demod
Range Gate
From TFI
100 yd Notch
Video & Notch Mixer
.22µs Delay
Video Amp
Range
Elev
Az
TRACK SWEEP GENERATOR
Exp Sweep Amp
Sweep Gen
Sweep Mixer
Amp & Dis-placer
Sel Sig
Norm
Off
On
LOBING AMPLIFIER
Square Wave Gen
Un-blank Mixer
Track Video Amp
Scope
Hor
Vert
TRACKING INDICATOR
TO AZIMUTH MAN SIGNAL
TRACKING RANGE COMPUTER
Tracking Range Generator
Range Mark Gate
Range Mark Select
Pip Select
Track Range Gate
To PI & TFI
To Acq Video & Mark Mixer
Pip Gen
8 to 144 V
120 to 12V
Acq-Trk Range Mark
Pip Gate Gen
PREKNOCK
Phase Shifter
TIMING WAVE GENERATOR
Main Gate Gen
Sine Wave Gen
Relay Amp
-28V
From Acq. Slew Circuit
From Range Slew Circuit
Sensing Relays
Slew Motor
Range Motor
FEEDBACK
RANGE MODULATOR
Auto-Aid-Man Select
Disable
Coast
Range Balance Network
Range Balance Mod
400 CPS
Auto Relay
Man-Aid
LP Servo Amp Rd
LP Servo Amp Rh
Coupling Network
(Clutch Engaged in Aid & Auto)

- (2) Pulse Synchronizer.
  - (a) Everything starts at the Pulse Synchronizer.
  - (b) The Pulse Synchronizer gets its power signal from a power supply in the radar cabinet.
  - (c) The Pulse Synchronizer generates a pulse signal 1000 times per second. (Student not told about the MT1 synchronizer establishing the pulse rate until later when Acquisition system is presented.)
  - (d) This signal triggers all activity within the Track system.
  - (e) The signal from the Pulse Synchronizer goes to the Pre-Knock Pulse (ignore at present) and to the Transmitter Pulse.
- (3) Transmitter Pulse.
  - (a) The Transmitter Pulse delays each pulse from the Pulse Synchronizer before sending it to the Trigger Generator.
  - (b) The signal remains the same but is delayed in the Transmitter Pulse. (1000 times per second.)
  - (c) This delayed signal is then sent to the Trigger Generator.
- (4) Trigger Generator.
  - (a) The Trigger Generator amplifies (slightly) the signal from the Transmitter Pulse.
  - (b) The Trigger Generator amplifies (increases the strength) the signal just enough to trigger the next Gray Box.
  - (c) This amplified signal goes to the Modulator.
- (5) Modulator.
  - (a) The Modulator receives its signal from the Trigger Generator.
  - (b) The Modulator amplifies this pulse signal about 100 times.
  - (c) The Modulator sends this highly amplified pulse signal to the Magnetron.
- (6) Magnetron.
  - (a) The Magnetron receives its signal from the Modulator.
  - (b) The Magnetron gives this pulse signal a radio frequency (RF) (which can be varied by adjustment) and transmits (or broadcasts) this frequency through the Wave Guide.
- (7) Wave Guide.
  - (a) The Wave Guide receives radio frequency waves from the Magnetron.
  - (b) The Wave Guide is essentially a rectangular hollow tube which guides these radio frequency waves from the Magnetron to the lens of the tracking antenna and to the AFC Mixer.
- (8) Lens (Tracking Antenna, outgoing waves).
  - (a) The lens of the tracking antenna receives radio frequency waves through the Wave Guide.
  - (b) The lens causes these radio frequency waves to be transmitted in a given direction.
  - (c) The radio waves leaving the lens are transmitted into space.
- (9) Target.
  - (a) Radio frequency waves are transmitted into space by the antenna as described above.
  - (b) If the waves hit NO targets, they are dissipated in space.
  - (c) If the waves engage anything of density such as airplanes, smoke stacks, trees, clouds, snowfall or fog banks, they bounce off these dense bodies and at least some will bounce back to the lens of the antenna. These returning waves are called target echo.
- (10) Lens (Tracking Antenna, incoming target echo).
  - (a) A few of the target echoes will strike the lens (1000 times per second).
  - (b) The lens deflects these target echoes through the Scanner (disregard at present) into the Wave Guide. The duplexer in the Wave Guide distinguishes the incoming from the outgoing signals and channels them in the appropriate directions.
- (11) Wave Guide and Duplexer.
  - (a) The target echoes are fed by the lens into the Wave Guide.
  - (b) The duplexer, which is located in the Wave Guide, separates the incoming target echoes from the outgoing pulses and directs the target echoes into the Receiver Mixer.
- (12) Receiver Mixer.
  - (a) The Receiver Mixer receives a signal both from the Wave Guide and from the Local Oscillator.
  - (b) The function of the Receiver Mixer is to mix the target echo and the signal from the Local Oscillator.
  - (c) The signal from the Receiver Mixer goes to the IF Pre-Amp.

(13) IF Pre-Amp.
  (a) The IF Pre-Amp receives its signal from the Receiver Mixer (and a signal from the AGC to be discussed later).
  (b) The IF Pre-Amp amplifies the signal, allowing only 5±60 megacycle signals to pass on.
  (c) The IF Pre-Amp passes its signal to the IF Attenuator.

(14) AFC Mixer.
  (a) The AFC Mixer receives a sample of the signal frequency from the Magnetron and a signal frequency from the Local Oscillator.
  (b) The AFC Mixer mixes these two frequencies and sends the resulting signal to the AFC Discriminator. This should be a 60 megacycle signal. Mixing the radio frequency waves of differing frequencies produces a wave of a frequency equalling the difference of those two frequencies. The Local Oscillator should be tuned 60 MC ABOVE the Magnetron, to produce the desired 60 megacycle signal.

(15) AFC Discriminator.
  (a) The AFC Discriminator receives its signal from the AFC Mixer.
  (b) The AFC Discriminator will pass signals from 55 to 65 megacycles only. The AFC Discriminator compares these signals to 60 megacycles and generates a DC voltage proportional to the difference (or error) between the signals.
  (c) This direct current voltage goes to the Oscillator Alternator.

(16) Oscillator Alternator.
  (a) The Oscillator Alternator receives a direct current voltage (error signal) from the AFC Discriminator.
  (b) On the basis of this error signal, the Oscillator Alternator tunes the Local Oscillator, so that we get a signal of exactly 60 megacycles above Magnetron frequency. (As the Oscillator Alternator tunes the Local Oscillator around 60 megacycles, a duo-light on the chassis will flicker rapidly.)

(17) Local Oscillator.
  (a) The Local Oscillator is a generator.
  (b) Tuned by the AFC Unit, it generates radio frequency waves 60 MC above the frequency of the Magnetron.
  (c) The Local Oscillator feeds its signal into the Receiver Mixer and the AFC Mixer.

(18) AFC Search Pulse.
  (a) The AFC Search Pulse is a generator.
  (b) The AFC Search Pulse generates a pulse signal every 10 seconds.
  (c) If the Local Oscillator is tuned within ± 5 MC of 60 MC above the Magnetron, the DC voltage from the AFC Discriminator so indicates and the pulse signal stops at the Oscillator Alternator. If, however, the Local Oscillator is not within ± 5 MC of 60 MC above the Magnetron, the AFC Search Pulse signals the Oscillator Alternator to drive the Local Oscillator up through its range of frequency and back down so that it will pick up its proper frequency. On the upgoing search, a circuit between the Oscillator Alternator and the AFC Discriminator keeps the AFC Discriminator from allowing the Local Oscillator to lock on frequency 60 MC below the Magnetron (up search cut-off).

(19) IF Attenuator.
  (a) The IF Attenuator receives its signal from the IF Pre-Amp.
  (b) The IF Attenuator, a five-position switch, reduces this signal so that signal strength is appropriate for the rest of the system.
  (c) The IF Attenuator sends the signal (60 MC) to the IF Amplifier.

(20) IF Amplifier.
  (a) The IF Amplifier receives its signal from the IF Attenuator.
  (b) The IF Amplifier amplifies the signal and passes it to the IF Detector.

(21) IF Detector.
  (a) The IF Detector receives its signal from the IF Amplifier.
  (b) The IF Detector takes out the 60 MC and passes on the video signal. (Signal that can be seen on a scope.)
  (c) The IF Detector sends its Video signal to the Video Amplifier.

(22) Video Amplifier.
  (a) The Video Amplifier receives its signal from the IF Detector.
  (b) The Video Amplifier amplifies the Video signal and sends it to the Sine Wave Detector, the Non-Delay Demodulator (to be discussed later) and to the .22 Micro-Second delay.

(23) .22 Micro-Second Delay.
  (a) The .22 Micro-Second Delay receives its signal from the Video Amplifier.
  (b) The .22 MS Delay delays the Video signal for .22 micro seconds and passes it on to the Delay Demodulator (to be discussed later) and to the Video and Notch Mixer.

(24) Video and Notch Mixer.
- (a) The Video and Notch Mixer receives its signal from the .22 MS Delay (Video signal) and a 100 Yard Notch signal from the 100 Yard Notch (to be discussed later).
- (b) The Video and Notch Mixer mixes the two incoming signals and passes them to the three Track Video Amplifiers (one each for Elevation, Azimuth, and Range).

(25) Track Video Amplifier(s).
- (a) The Track Video Amplifiers receive their signals from the Video and Notch Mixer.
- (b) The Track Video Amplifier amplifies these signals (100 Yard Notch and Video signals, the only vertical signals which appear on the scopes).
- (c) The vertical signals go from the Track Video Amplifier into the vertical plates of all the "A" scopes where they form part of the scope presentation.

NOTE: Explain the 3 to 1 ratio of the Block Diagram drawing as it pertains to the Tracking Indicators.

(26) Pre-Knock Pulse.
- (a) The Pre-Knock Pulse receives its pulse signal from the Pulse Synchronizer.
- (b) The Pre-Knock Pulse generates the pulse signal which activates all the Gray Boxes it feeds into.
- (c) The Pre-Knock Pulse feeds its signal to the Main Gate Generator and the Pip Gate Generator (to be discussed later) and to the three Sweep Generators (one per "A" scope).

(27) Sweep Generator.
- (a) The three Sweep Generators receive their signals from the Pre-Knock Pulse.
- (b) The Sweep Generator generates the 615 Micro-Second gate signal produces the Main Sweep on the "A" scopes.
- (c) The Sweep Generator passes its signal to the Sweep Mixer and to the Unblanking Mixer (in NORMAL and OFF scope modes, to be discussed later).

(28) Sweep Mixer.
- (a) The Sweep Mixer receives a signal from the Expanded Sweep Amplifier (to be discussed later) and from the Sweep Generator.
- (b) The Sweep Mixer mixes these two signals and passes them to the Amplifier and Displacer.

(29) Amplifier and Displacer.
- (a) The Amplifier and Displacer receives its signals from the Sweep Mixer and reference information from the Lobing Generator (to be discussed later).
- (b) The Amplifier and Displacer amplifies and passes the horizontal signals on to the horizontal plates of the three "A" scopes.

(30) Main Gate Generator.
- (a) The Main Gate Generator receives its timing signal from the Pre-Knock Pulse.
- (b) The Main Gate Generator generates the main gate or 620 Micro-Seconds gate, a signal which is shaped and timed to allow the next Gray Box, the Sine Wave Generator, to perform its function.

(31) Sine Wave Generator.
- (a) The Sine Wave Generator receives its 620 MS gate signal from the Main Gate Generator.
- (b) The Sine Wave Generator generates 51 sine waves for each 620 Micro-Seconds gate signal from the Main Gate Generator.
- (c) These sine waves are sent to the Phase Shifter.

(32) Phase Shifter.
- (a) The Phase Shifter receives sine waves from the Sine Wave Generator and a mechanical drive from the Range Drive Motor, reflecting the position of the range handwheel.
- (b) The drive from the motor causes the phase shifter to shift the 51 sine waves slightly forward or back.

  NOTE: Explain 51 sine waves in 620 Micro-Seconds space equals about 100,000 yards. By shifting we cover the entire range and all area within that range.

- (c) The Phase Shifter sends the sine waves to the Pip Generator and a voltage from 8 to 144V to the Pip Selector showing the position of the range handwheel to the Pip Selector.

(33) Pip Generator.
- (a) The Pip Generator receives sine waves from the Phase Shifter.
- (b) The Pip Generator converts the 51 sine waves into 51 pip signals (1000 times per second).
- (c) The Pip Generator sends its signal (51 pips) to the Range Mark Select (to be discussed later) and to the Pip Selector.

(34) Pip Selector and Pip Gate Generator.
- (a) The Pip Selector receives pips from the Pip Generator, a voltage from the Phase Shifter showing the position of (range factor) the range handwheel, and a signal 620 MS long from the Pip Gate Generator. This signal from the Pip Gate Generator decreases from 130V to 0V and represents the amplitude of the main sweep.
- (b) The Pip Selector matches the voltage of the Pip Gate Generator to the voltage from the Phase Shifter and on the basis of this matching selects the pip (2,000 yards between pips) which is nearest, in terms of distance, to the range setting of the range handwheel.
- (c) This selected pip is sent to the Track Range Gate.

(35) Track Range Gate.
- (a) The Track Range Gate receives its signal from the Pip Selector.
- (b) The Track Range Gate generates the signal (Track Range Gate) which allows the displaying of the track azimuth portion of the electronic cross on the PPI scope.
- (c) The Track Range Gate sends its signal to the Acquisition Video and Mark Mixer, and to the PI and TFI, and the Range Mark Gate and the Acq-Track Range Mark.

(36) Acq-Track Range Mark.
- (a) The Acq-Trk Range Mark receives its signal from the Track Range Gate.
- (b) The Acq-Trk Range Mark generates the signal that puts the range mark portion of the electronic cross on the PPI scope.
- (c) The Acq-Trk Range Mark sends its signal to the Acquisition Video and Mark Mixer.

(37) Range Mark Gate.
- (a) The Range Mark Gate receives its signal from the Track Range Gate.
- (b) The Range Mark Gate delays the gate signal.
- (c) The Range Mark Gate passes this delayed signal to the Range Mark Select.

(38) Range Mark Select.
- (a) The Range Mark Select receives a delayed gate signal from the Range Mark Gate.
- (b) Triggered and timed by the signal from the Range Mark Gate, the Range Mark Select selects the pip just following the pip selected by the Pip Selector.
- (c) The Range Mark Select sends this signal to the 500 Yard Expanded Sweep.

(39) 500 Yard Expanded Sweep.
- (a) The 500 Yard Expanded Sweep receives its signal from the Range Mark Select.
- (b) The 500 Yard Expanded Sweep generates a .3 Micro-Second (3 MS = 500 yards) gate signal which puts the 500 Yard Expanded Sweep on the face of the "A" scopes and the Trial Fire Indicator.
- (c) The 500 Yard Expanded Sweep sends its signal to the Expanded Sweep Amplifiers of all three "A" scopes. The sweep signal is then sent to the Sweep Mixer, then through the Amplifier and Displacer on to the horizontal plates of the three "A" scopes.
- (d) The 500 Yard Expanded Sweep, when the system is in SELECTED signal, sends its signal to the Unblanking Mixer (to be discussed later).
- (e) The 500 Yard Expanded Sweep sends its signal (.3 MS gate) to the Network Driver.

(40) Network Driver.
- (a) The Network Driver receives its signal (.3 MS gate) from the 500 Yard Expanded Sweep.
- (b) The Network Driver generates a 1.3 MS trigger signal which is sent to the Range Gate (to be discussed later).
- (c) The Network Driver also generates a 1.2 MS trigger signal which goes to the Clear Out Pulse.

(41) Clear Out Pulse.
- (a) The Clear Out Pulse receives its signal from the Network Driver.
- (b) The Clear Out Pulse inverts and mirrors this signal without changing its size or time length.
- (c) The Clear Out Pulse sends its signal to the Sine Wave Detector (to be discussed later) and to the 100 Yard Notch.

(42) 100 Yard Notch.
- (a) The 100 Yard Notch receives the 1.2 MS signal from the Clear Out Pulse.
- (b) The trailing edge of the signal from the Clear Out Pulse triggers the 100 Yard Notch and causes it to generate a gate signal 0.6 micro-second long. This is the signal which puts the 100 Yard Notch on the face of the "A" scopes.
- (c) The 100 Yard Notch sends its signal to the Video and Notch Mixer, where the 100 Yard Notch signal is mixed with Video signal (all vertical signals) and is sent to the three Track Video Amplifiers and to all the "A" scopes.

(43) Lobing Generator.
- (a) The Lobing Generator is mounted on the track antenna. It rotates as the Wave Guide rotates.

(b) The Lobing Generator generates a signal that tells the rest of the system where it is on the antenna (top, left bottom, or right side of the antenna) at which position the target echo is presently being received.

(c) The Lobing Generator sends this reference information to the following Gray Boxes:

1) Elevation and Azimuth lobing reference amplifiers (to be discussed later).

2) To the square wave generator in Azimuth and Elevation (to be discussed later).

3) In NORMAL and SELECTED signal to the Amplifier and Displacers of the Elevation and Azimuth "A" scopes.

(44) Amplifier and Displacer (NORMAL and SELECTED signal scope modes).

(a) In NORMAL and SELECTED signal scope modes the Amplifier and Displacer (Azimuth and Elevation) receives reference information from the Lobing Generator.

(b) This left-right (or up-down) reference information triggers the Amplifier and Displacer and causes it to displace the scope picture horizontally to give us two signals in NORMAL and SELECTED signal (Elevation and Azimuth only).

LESSON PLAN

INSTRUCTIONAL UNIT: SYMPTOMS.

TYPE: Conference.

TIME ALLOTTED: Six (6) hours.

CLASS PRESENTED TO: Class as designated.

TOOLS, EQUIPMENT, AND MATERIALS: One lined Block Diagram per student and instructor.

PERSONNEL: None

INSTRUCTIONAL AIDS: Chalkboard, w/chalk.

REFERENCES: None

STUDY ASSIGNMENTS: None

STUDENT UNIFORM AND EQUIPMENT: Uniform, as designated. Equipment, None.

TROOP REQUIREMENTS: None

TRANSPORTATION REQUIREMENTS: None

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1. PRESENTATION. (Conference, six hours.)

a. Introduction. (Conference, three minutes.)

(1) Objective. The objective of this period of instruction is to have the students acquire a knowledge of the symptoms presented by common M33 malfunctions.

(2) Standards. The students should, at the conclusion of this period of instruction, be able to recognize and interpret all the symptoms discussed in this unit of instruction.

(3) Reasons. The accurate interpretation of symptoms is the foundation for efficient and accurate trouble shooting.

b. Explanation. (Conference, two hours.)

(1) General. Symptoms are the manifestation of a malfunction. To appreciate symptoms properly, we must approach a malfunctioning M33 systematically. We must attempt to completely energize the system, to include scope intensities, and attempt to operate the set in Manual Aided and Automatic in all scope modes. We assume only one malfunction occurs at any given time.

(2) Scope Symptoms. In the interpretation of scope symptoms, we should first determine what is missing from or wrong with the scopes. We should then determine how many scopes present this malfunction—one, two, or three. We should then find where a signal starts that could cause this malfunction to occur and we will find our malfunction between where it might be and where it is proven not to be.

(a) Grass is to a scope what static is to a radio. It is fed into the system from between the Pulse Synchronizer to the IF Pre-Amp. There are many sources of grass and not all of them will malfunction at the same time; so, if we don't have grass on the scope, it is caused by a malfunction in some box passing the grass (IF Pre-Amp to Video Notch Mixer), not something generating the grass. If we don't have grass we will not have Target Echo.

(b) Target Echo. If we can't get Target Echo on the face of the scope and we have grass, our malfunction then must be in some Gray Box behind the IF Pre-Amp.

(c) 100 Yard Notch. If all three scopes are missing the 100 Yard Notch, it must be a malfunction in something generating or passing the 100 Yard Notch (not within the tracking indicator). If we have an Expanded Sweep on the face of the scopes we know that the Network Driver is receiving adequate signal. Our malfunction must be between the Network Driver and the Video and Notch Mixer. (The Video and Notch Mixer can pass Video and not pass the Notch signal.) If we have no 100 Yard Notch on one scope the malfunction must then be in the Track Video Amplifier, the only Gray Box dealing with vertical signals within a single tracking indicator.

(d) Main Sweep.

1) If we have no Main Sweep on any scope, the malfunction must be in the Pre-Knock Pulse or the Pulse Synchronizer. If the Magnetron will energize, we know it is Pre-Knock Pulse; contrarywise, if the Magnetron will not energize, we know our malfunction must be in the Pulse Synchronizer.

2) If we have no Main Sweep on one scope, our malfunction must be between the Sweep Generator and the Amplifier and Displacer.

(e) 500 Yard Expanded Sweep.

1) If we have no 500 Yard Expanded Sweep on three scopes, our malfunction must be between the 500 Yard Expanded Sweep and the Main Gate Generator. (Presence of Main Sweep tells us that Pre-Knock Pulse is functioning properly.)

NOTE: Explain at this point that the Acq-Trk Range Mark will not affect the presence or absence of the 500 Yard Expanded Sweep in any way.

2) If we have no 500 Yard Expanded Sweep, we will have no 100 Yard Notch and we won't be able to Auto Trk in Range. (The Network Driver will not be functioning.)

3) Absence of the 500 Yard Expanded Sweep on one scope indicates a malfunction in the Expanded Sweep Amplifier or the Sweep Mixer.

(f) Target Echo missing from the face of one scope. (Grass is present.) Our malfunctioning must be behind the IF Pre-Amp. Presence of Main Bang on the scope tells whether or not the Magnetron is working.

(g) No electronic cross indicates a malfunction between the Pip Gate Generator and the Acq-Trk Range Gate. No electronic cross and no 500 Yard Expanded Sweep indicates a malfunction in the Pip Selector or the Acq-Trk Range Gate. Absence of 500 Yard Expanded Sweep, but presence of electronic cross, means that the Pip Gate Generator and the Pip Selector are not stopping the electronic cross signal, but the Acq-Trk Range Gate may be.

(h) Absence of all vertical signals on all scopes indicates malfunction in the Video and Notch Mixer. It can pass Video and not pass the Notch signal, or the contrary may be true or it may pass neither Video nor Notch signal.

(i) Any distortion of vertical scope presentation of just one scope is caused by a malfunction in the Track Video Amplifier.

(j) Presence of one rather than two Target Echoes in NORMAL and SELECTED signal on both the Azimuth and Elevation scopes indicates a malfunction in the Lobing Generator. The same condition on only one scope indicates a malfunction in the Amplifier and Displacer.

(k) No light of any sort on one scope indicates that that scope is bad. (Or that the scope itself is malfunctioning.)

(3) Operational Symptoms.

(a) Failure to track in Manual in Range may be caused by a malfunction in one of the following Gray Boxes: Handwheel, Handwheel Drive, Coupling Network, Low Power Servo Amp R_h, Auto Relay, or motor.

(b) Failure to track in Aided in Range, Elevation, or Azimuth when the system will track manually, may be caused by a malfunction in the Rate Control, a connection between the Handwheel Drive and the Rate Control, or in the Coupling Network.

(c) Failure to track automatically in Range (range only), if the system will track in Manual and Aided, is caused by a malfunction in the Range Balance Modulator, Range Balance Network, Coupling Network, Low Power Servo Amp R_D, Auto Relay, or the motor.

(d) Failure to Auto Track in Range, Elevation, and Azimuth (Coast Disable switch in Coast position) is caused by a malfunction in the Network Driver, Range Gate, Non-Delay and Delay Modulator, or Auto-Aid-Man Selector.

(e) Failure to track manually in either Azimuth or Elevation is caused by a malfunction in the Handwheel, Handwheel Drive, Coupling Network, Low Power Servo Amp R_h, or Low Power Servo Amp A_h, Auto Relay, Intermediate Drive, Low Power Servo Pre-Amp, Low Power Servo Amp, Main Drive, or Antenna.

(f) Failure to Auto Track in both Elevation and Azimuth is caused by a malfunction in the Sine Wave Detector, Sine Wave Smoother, or Lobing Generator.
(g) Failure to Auto Track in either Elevation or Azimuth (not both) is caused by a malfunction in the Lobing Reference Amplifier, Phase Detector, Balanced Modulator, or Auto Relay.
(h) Failure to continue tracking lost target is caused by a malfunction in the feedback chain.

2. APPLICATION. (Conference three and one half hours.)
   Present symptoms and question students on what Gray Boxes could malfunction to cause that scope symptom to appear.

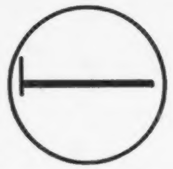
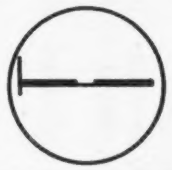
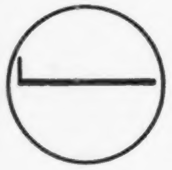
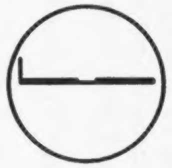
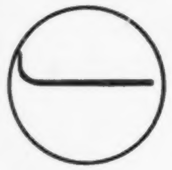
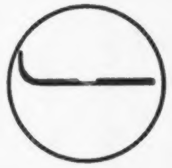
3. REVIEW. (Conference, one half hour.)
   a. Clarify points of difficulty by asking students if they have any questions.
   b. Summary.
      (1) Review major symptoms.
      (2) Reiterate important scope symptoms on one or three scopes.
   c. Closing statement. The study of symptoms is the most important subject we have yet discussed. Accurate interpretations of the symptoms is the foundation for efficient trouble shooting.

GRAY BOX CHECK POINTS

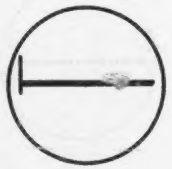
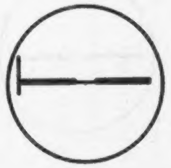
When taking Check Point readings the following should be observed:

1. Set Test Amplifier Gain at maximum.
2. Set Test Amplifier Attenuator as specified on Check Point sheet.
3. Set Range Dial at 50,000 yards.
4. Set IF Attenuator at 15 unless otherwise specified.
5. Set TS-352 at 20,000 Ohms per volt scale, when measuring DC voltage.
6. Set TS-352 at 10,000 Ohms per volt scale, when measuring AC voltage.

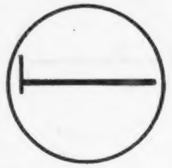
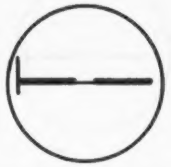
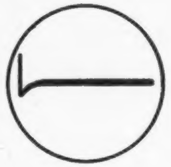
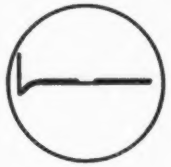
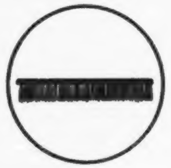
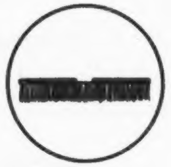
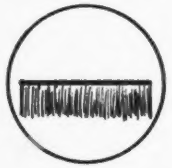
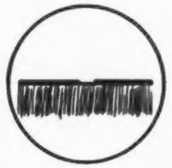
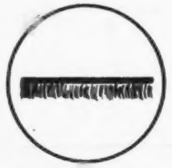
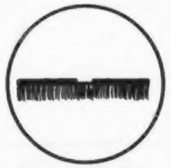
NOTE: Wave forms and meter readings may vary slightly from those pictured or listed.
NOTE: Schematic numbers and tube numbers are associated with the underlined Gray Box.

SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS		
				WO/EXP SWEEP		W/EXP SWEEP
1	Pulse Synchronizer to Transmitter Pulse Pre-Knock	V1 & V2	V2, Pin 2 Pulse Synch		Test Amp Atten Set at 50	
2A	Transmitter Pulse to Trigger Generator	V5	J4 (P35) Trans Pulse J1 (P1) Trigger Gen Track H.V. Meter (Mag must be ON)		Test Amp Atten Set at 10 P.S. cur. - 45 Mag cur. - 6 P.S. volt. - 8	
3	Trigger Generator to Modulator	V1 & V2	J2 Trigger Gen J1 (P1) Modulator Track H.V. Meter (Mag must be ON)		Test Amp Atten Set at 50 P.S. cur. - 45 Mag cur. - 6 P.S. volt. - 8	
4	Modulator to Magnetron	V1, V2, V3	Reverse Cur. Meter Track H.V. Meter (Mag must be ON)		Reverse Current Meter - 6 P.S. cur. - 45 Mag cur. - 6 P.S. volt. - 8	
6	Magnetron to Duplexer	V2 & V3	Reverse Cur. Meter Track H.V. Meter (Mag must be ON)		Reverse Current Meter - 6 P.S. cur. - 45 Mag cur. - 6 P.S. volt. - 8	
7A	Duplexer	TR V6 ATR V4, V5	Wave Guide (Mag must be ON)		No arching in Wave Guide	

(Continued)

SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS		
				WO/EXP SWEEP		W/EXP SWEEP
8A	AFC Mixer	CR3, CR4	AFC CC Meter (Mag must be ON)		AFC CC Meter (CR3) - 1.75 AFC CC Meter (CR4) - 1.75 (Can be adjusted)	
8B	Receiver Mixer	CR1, CR2	Signal CC Meter (Mag must be ON)		Signal CC Meter (CR1) - 1.75 Signal CC Meter (CR2) - 1.75 (Can be adjusted)	
9	AFC Discriminator	V1, V2, V3, V4A	AFC Hunt Light (Mag must be ON)		Constant flickering of hunt light	
10	AFC Search Pulse	V7	AFC Hunt Light (Mag must be OFF)		Light changes sides every nine seconds ± one second	
11	Oscillator Alternator	V4B, V5, V6, V8	AFC Hunt Light (Mag must be OFF)		Light changes sides every nine seconds ± one second	
12A	Local Oscillator	V7	AFC CC Meter Sig CC Meter (Mag must be ON)		Both read 1.75 (Can be adjusted)	
12B	Tuning Drive		AFC CC Meter Sig CC Meter (Mag must be ON)		Both read 1.75 (Can be adjusted)	
13	IF Pre-Amplifier to IF Attenuator	V1, V2, V3, V4, V5	J4 (P67) IF Atten (Mag must be ON)		Test Amp Atten Set at 2	

(Continued)

SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS		
				WO/EXP SWEEP		W/EXP SWEEP
14	IF Attenuator to IF Amplifier		J5 (P2) IF Atten J2 (P3) IF Amp (Mag must be ON)		Test Amp Atten Set at 2 IF Atten Set at 5	
15	IF Amplifier to IF Detector	V1, V2, V3, V4, V5	V6, Pin 1 IF Detect (Use 7 Pin Min. Tube Adapter) (Mag must be ON)		Test Amp Atten Set at 2	
16	IF Detector to Video Amplifier	V6	P1 (J1), Pin 3 IF Detect V19, Pin 1 + C42 Video Amp		Test Amp Atten Set at 2 Negative grass (Small Amp)	
17	Video Amp to .22 μs Delay, Non-Delay Demod, Sine Wave Detect	V19, V20 V21	Z1, Pin 1 .22 μs Delay V9, Pin 1 N.D. Demod V13, Pin 1 + R92 + CR2 S.W. Detect		Test Amp Atten Set at 2 Negative grass (Large Amp)	
18A-1	.22 μs Delay to Video & Notch Mixer		Z1, Pin 3 + R96 + R97 at end of Coaxial Cable .22 μs Delay V7, Pin 2 Video & Notch Mixer		Test Amp Atten Set at 2 Negative grass (Small Amp)	

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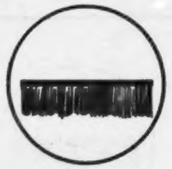
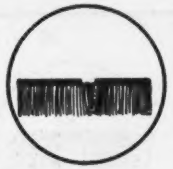
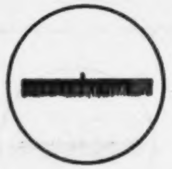
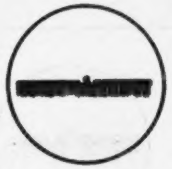
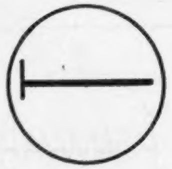
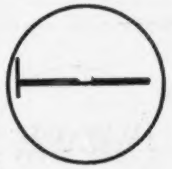
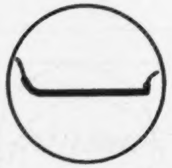
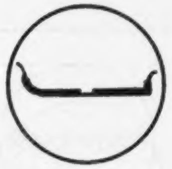
SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS		
				WO/EXP SWEEP		W/EXP SWEEP
18A-2	.22 μs Delay to Delay Demodulator		Z1, Pin 3 .22 μs Delay V11, Pin 1 D. Demod		Test Amp Atten Set at 2 Negative grass (Large Amp)	
18B	Video & Notch Mixer to Track Video Amp	V7	J3(P65) Video & Notch Mixer (Put 75 OHM Resistor on "Operate" Connector J55 to see Notch)		Test Amp Atten Set at 2 Negative grass (Very small Amp)	
41	Track Video Amp	V1, V2, V3, V4	Substitute Chassis	Grass and 100 yard Notch must appear on scope.		
2B	Pre-Knock Pulse to Main Gate Gen, Pip Gate Gen, Sweep Gen, Relay Amp	V4	J3(P34) Pre-Knock V8, Pin 2 M. Gate Gen V7, Pin 2 Pip Gate Gen J1(P2) Sweep Gen J3(P70) Relay Amp		Test Amp Atten Set at 2	
19	Main Gate Gen to Sine Wave Gen	V8 & V9	J2(P2) at end of Coaxial Cable Main Gate Gen V1, Pin 3 Sine Wave-Gen		Test Amp Atten Set at 10	

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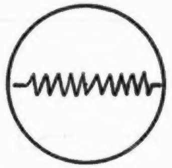
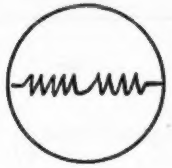
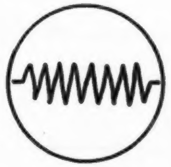
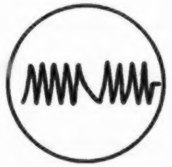
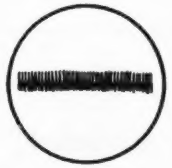
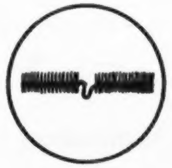
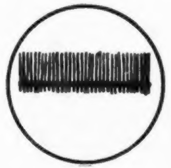
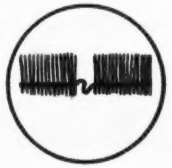
SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WO/EXP SWEEP	WAVE FORMS and METER READINGS	W/EXP SWEEP
20	Sine Wave Gen to Phase Shifter	V1 & V2	Z2, Pin 2 Z2, Pin 3 } Sine Wave Gen (Pin 2 reverses presentation)		Test Amp Atten Set at 10 (51 sine waves)	
21-1	Phase Shifter to Pip Generator	V3, V4, V5	V5, Pin 5 Ph. Shifter J1(P1) at end of Coaxial Cable Pip Gen		Test Amp Atten Set at 10 (51 sine waves)	
21-2	Phase Shifter to Pip Selector	V3, V4, V5	V17, Pin 2 Pip Select	Positive DC voltage varies from 12 to 130 V depending upon setting of Range Dial		
22-1	Pip Generator to Pip Selector	V1 & V2	V2, Pin 6 & R22 Pip Generator V12, Pin 1 & C28 Pip Selector		Test Amp Atten Set at 10 (51 Pips)	
22-2	Pip Generator to Range Mark Select	V1 & V2	V2, Pin 6 Pip Gen V16, Pin 1 Range Mark Select		Test Amp Atten Set at 10 (51 Pips - larger Amp than above)	

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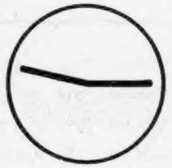
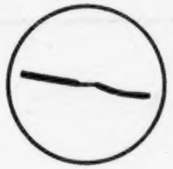
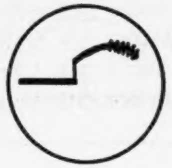
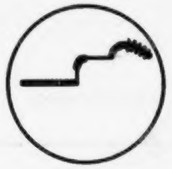
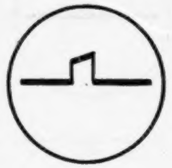
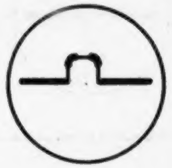
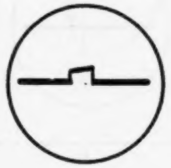
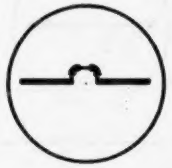
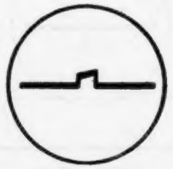
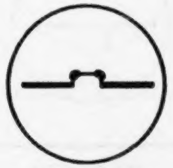
SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS		
				WO/EXP SWEEP		W/EXP SWEEP
23	Pip Gate Gen to Pip Select	V7, V10, V11	TP2 Pip Gate Gen		Test Amp Atten Set at 50	
24	Pip Selector to Track Range Gate	V12, V13, V14, V17	V14, Pin 5 Pip Sel.		Test Amp Atten Set at 10	
25-1	Track Range Gate to Track Range Mark	V3 & V4A	V3, Pin 1 Track Range Gate V4, Pin 7 Track Range Mark		Test Amp Atten Set at 50	
25-2	Track Range Gate to Range Mark Gate	V3 & V4A	V15, Pin 3 Range Mark Gate		Test Amp Atten Set at 50 (Smaller Amp than above)	
25-3	Track Range Gate to P1 & TF1	V3 & V4A	V4, Pin 3 Track Range Gate		Test Amp Atten Set at 50 (Smaller Amp than above)	

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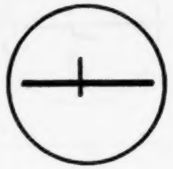
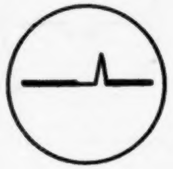
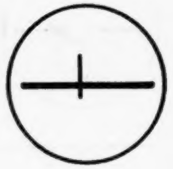
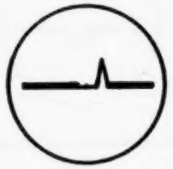
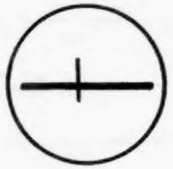
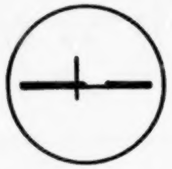
SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS		
				WO/EXP SWEEP		W/EXP SWEEP
26-1	Track Range Mark to Relay Amp	V4B, V5, V6	T2, Pin 1 Track Range Mark J1(P68) Relay Amp		Test Amp Atten Set at 10	
26-2	Track Range Mark to Video & Mark Mixer	V4B, V5, V6	T2, Pin 1 Track Range Mark		Test Amp Atten Set at 10	
27-1	Acq Range Comp to Relay Amp	V1, V2, V3, V4, V5, V6	J2(P69) Relay Amp		Test Amp Atten Set at 10 (Acq Range Circle set at 40,000 yds)	
27-2	Relay Amp to Sensing Relay	V1, V2, V3, V4, V5, V6	V4, Pin 6 Relay Amp V5, Pin 6 Relay Amp	100V AC except when slew out in Range 45V DC when slew out in Range 100V AC except when slew in in Range 45V DC when slew in in Range		
48-1	Sensing Relay to Slew Motor		E3, Pin 5 Slew Motor E3, Pin 3 Slew Motor	100V AC when slew in in Range 100V AC when slew out in Range 170V AC when slew in in Range 240V AC when slew out in Range		

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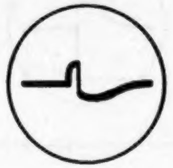
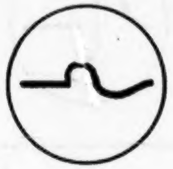
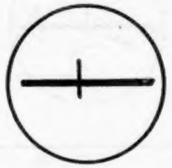
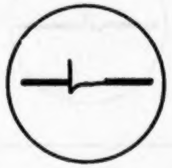
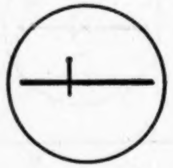
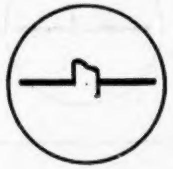
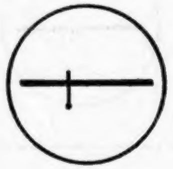
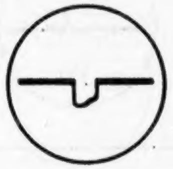
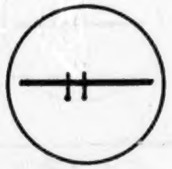
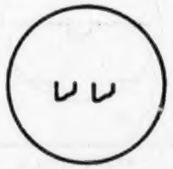
SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS		
				WO/EXP SWEEP		W/EXP SWEEP
29	Range Mark Gate to Range Mark Selector	V15	V15, Pin 6 Range Mark Gate V16, Pin 7 Range Mark Select		Test Amp Atten Set at 50	
30	Range Mark Selector to 500 Yd Expanded Sweep	V16	J7(P53) Range Mark Sel. J1(P66) 500 Yd Expanded Sweep		Test Amp Atten Set at 10	
31-1	500 Yd Expanded Sweep to Network Driver	V1 & V4	V4, Pin 6 500 Yd Expanded Sweep V2, Pin 1 Net. Driver		Test Amp Atten Set at 10	
31-2	500 Yd Expanded Sweep to Expanded Sweep Amp	V1 & V4	J2(P64) 500 Yd Expanded Sweep J2(P1) Expanded Sweep Amp		Test Amp Atten Set at 10	
36-1	Expanded Sweep Amp to Unblank Mixer (Sel. Sig. only)	V5	J2(P1) Expanded Sweep Amp V3, Pin 7 & R17 Unblanking Mixer		Test Amp Atten Set at 10	

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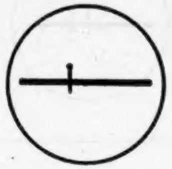
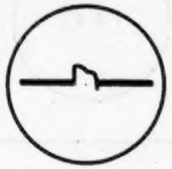
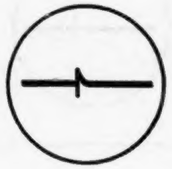
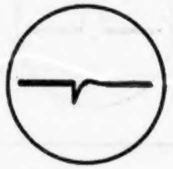
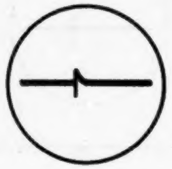
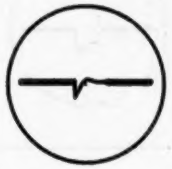
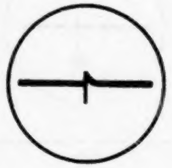
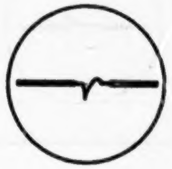
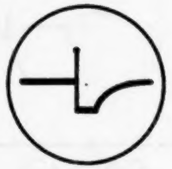
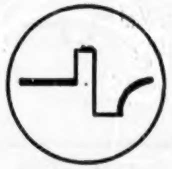
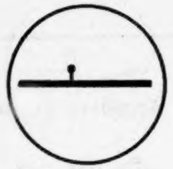
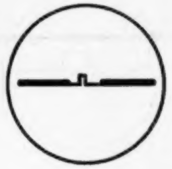
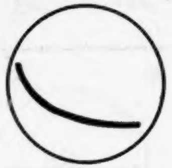
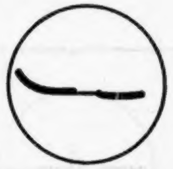
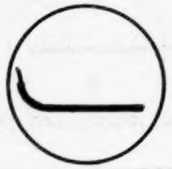
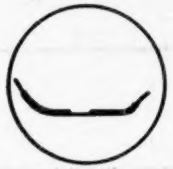
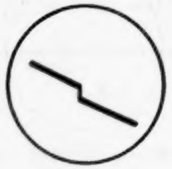
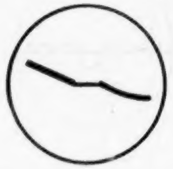
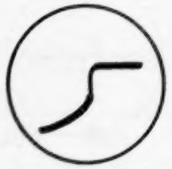
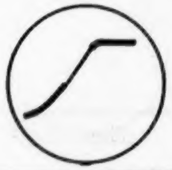
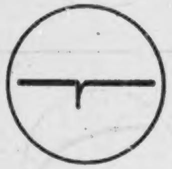
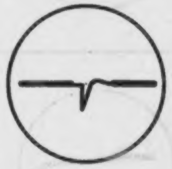
SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS		
				WO/EXP SWEEP		W/EXP SWEEP
36-2	Expanded Sweep Amp to Sweep Mixer	V5	V5, Pin 5 Expanded Sweep Amp V6, Pin 1 Sweep Mixer		Test Amp Atten Set at 10	
32-1	Network Driver to Clear Out Pulse	V2	Z3, Pin 2 Net. Drive V3, Pin 1 Clear Out Pulse		Test Amp Atten Set at 50	
32-2	Network Driver to Range Gate	V2	Z2, Pin 2 Net. Driver V5, Pin 1 Range Gate		Test Amp Atten Set at 50	
33-1	Clear Out Pulse to 100 Yd Notch	V3	Z4, Pin 2 Clear Out Pulse V8, Pin 3 100 Yd Notch		Test Amp Atten Set at 10	
33-2	Clear Out Pulse to Sine Wave Detector	V3	V3, Pin 6 Clear Out Pulse V15, Pin 7 Sine Wave Detector		Test Amp Atten Set at 2	

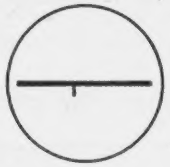
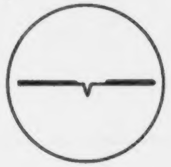
(Continued)

SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS WO/EXP SWEEP		W/EXP SWEEP
34	100 Yd Notch to Video & Notch Mixer	V8	V8, Pin 8 & R159 100 Yd Notch (Remove V7) V7, Pin 3 Video & Notch Mixer (Remove V7) (Place 75 OHM Resist. on "Operate" Connector J55 to see Notch)		Test Amp Atten Set at 2	
35-1	Sweep Gen to Sweep Mixer	V1 & V2	V2, Pin 8 Sweep Gen V3, Pin 2 Sweep Mixer		Test Amp Atten Set at 10	
35-2	Sweep Gen to Unblanking Mixer	V1 & V2	V3, Pin 7 & R17 Unblanking Mixer		Test Amp Atten Set at 2	
37	Sweep Mixer to Amplifier and Displacer	V3 & V7	V3, Pin 8 Sweep Mixer V4, Pin 2 Amplifier & Displacer		Test Amp Atten Set at 10	
38	Amplifier and Displacer to Scope	V4	EL: A} Amplifier & EL: B} Displacer (B will give opposite of A)		Test Amp Atten Set at 10	

(Continued)

SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS WO/EXP SWEEP	 W/EXP SWEEP
7B-1	Lobing Generator to Amplifier and Displacer (Normal and Sel. Sig.)		V4, Pin 7 & R35 Amplifier & Displacer	AC voltage between 20V and 50V	
7B-2	Lobing Generator to Square Wave Gen		V1, Pin 1 Square Wave Gen V1, Pin 5	AC voltage between 20V and 50V	
39	Square Wave Gen to Unblanking Mixer	V1 & V2	V3, Pin 3 Unblanking Mixer	70 Volts AC voltage	
40	Unblanking Mixer to Scope	V3 & V4	Substitute Chassis	Full presentation on scope without retrace	
43	Range Gate to Non-Delay and Delay Demod	V5, V6, V14	V14, Pin 8 Range Gate V11, Pin 2 Delay Demod V9, Pin 2 Non-Delay Demod	 Test Amp Atten Set at 10 (Non-Delay and Delay Demod give small Amp signal)	
44 A & B-1	Non-Delay and Delay Demodulator to Range Balance Network	V9, V10A N.D. V11, V12A D.D.	V12, Pin 2 Delay Demod V10, Pin 2 N.D. Demod P1, Pin 1 Range Bal. P1, Pin 5 Network (Read 50V DC scale)	8V DC voltage 8V DC voltage 8V DC voltage 8V DC voltage (Reads slightly more with a target in Notch)	

(Continued)

SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS	
				WO/EXP SWEEP	W/EXP SWEEP
44 A&B-2	Non-Delay and Delay Demodulator to Auto-Aid-Man Select	V9, V10A N.D. V11, V12A D.D.	V10, Pin 2 N.D. Demod V12, Pin 2 Delay Demod V4, Pin 6 A.A. Man Sel. (Read 50V DC scale)	8V DC voltage 8V DC voltage 8V DC voltage (Reads slightly more with a target in Notch)	
44 A&B-3	Non-Delay and Delay Demodulator to Sine Wave Detect	V9, V10A N.D. V11, V12A D.D.	Junction of V9, Pin 7 + R71 and V11, Pin 7 + R87 N.D. Demod and D.D. V13, Pin 7 Sine Wave Detector	 Test Amp Atten Set at 10	
46	Auto-Aid-Man Selector to Auto Tracking Circuits	V4 & V5	P1(J54), Pin 12 Auto-Aid-Man-Select	-28V DC Voltage (Coast-Disable switch in Coast position) Zero voltage with target in Notch	
47	Range Balance Modulator to Range Coupling Network (Auto only)	V1, V2, V3	P1, Pin 4 Range Coupling Network	Small AC Voltage (Must unbalance Range Balance #2)	
48-2	Sensing Relay to Range Coupling Network		P1, Pin 6 Range Coupling Network	Small DC voltage as Range Dial oscillates about a midpoint when the Acq Slew Switch is held.	
50-1	Range Coupling Network to LPSAR_d		P1, Pin 8 Range Coupling Network P1, Pin 3 LPSAR_d	Small DC Voltage (when turning handwheel the voltage decreases slightly)	

(Continued)

SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS WO/EXP SWEEP	W/EXP SWEEP
50-2	Range Coupling Network to LPSA$_{R_h}$ (Man, Aid only)		P1, Pin 5 Range Coupling Network P1, Pin 3 LPSA$_{R_h}$	Small DC voltage (when turning handwheel the voltage decreases slightly)	
51	Low Power Servo Amplifier	V1, V2, V3, V4	P1, Pin 11 LPSA	AC voltage, strength depending upon rate of turning handwheel	
52-1	Sine Wave Detect to AGC	V12B, V13, V15	V17, Pin 3 AGC (Read 50 volt scale)	8V DC voltage (Slightly higher with target in Notch)	
52-2	Sine Wave Detect to Sine Wave Smoother	V12B, V13, V15	V15, Pin 3 Sine Wave Detector	32V DC voltage	
53	AGC to IF Pre-Amplifier	V10B, V17, V18	Between TP2 (AGC) and TP1 (GND) AGC (Test-Operate switch on Pulse Demod in Test position)	-3V (Can be adjusted) DC voltage	
54	Sine Wave Smoother to Phase Detector	V16	T1 between 3 and 4, T1 between 4 and 5, Sine Wave Smoother	Small AC voltage	
7B-3	Lobing Generator to Lobing Ref Amp		V1, Pin 7 and R5 V1, Pin 3 and R1 Lobing Ref Amp	50V AC voltage	
55	Lobing Reference Amp to Phase Detector (AZ or Elevation)	V1 & V2	V2 between Pin 8 and Pin 3 Lob Ref Amplifier T1 between Pin 4 and Pin 6 Phase Detect	170V AC voltage	

(Continued)

SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS WO/EXP SWEEP	W/EXP SWEEP
57	Balance Mod to Coupling Network (AZ or Elevation) (Auto only)	V5 & V6	T2 between 1 and 3 Balance Mod P1, Pin 4 Coupling Net.	Small AC voltage when balance Mod is unbalanced	
63	High Power Servo Pre-Amp to High Power Servo Amp (AZ or Elev)	V1, V2, V3, V4, V5	AZ Pre-Amp Out TP 1 and 2 Elev Pre-Amp Out TP 1 and 2 Located on HPSA frames	Small AC voltage when turning handwheel	
64	High Power Servo Amp to Main Drive (AZ or Elev)	V1 & V2	HP Servo Out TP 1, 2, 3, 4 Plus Neutral (AZ) HP Servo Out TP 1 Plus Neutral (Elev)	Small AC voltage when turning handwheel	
59-1	Main Drive (Feedback) to Azimuth Coupling Network		P1, Pin 15 AZ Coupling Network	Small AC voltage when turning handwheel	
58-1	Main Drive (Feedback) to Elevation Coupling Network		P1, Pin 15 Elevation Coupling Network	Small AC voltage when turning handwheel	
48-3	Rate Control (Range) to Coupling Network (Aided)		E1: 5 Range Handwheel Drive P1, Pin 1 Range Coup Net.	Small AC voltage when turning handwheel	

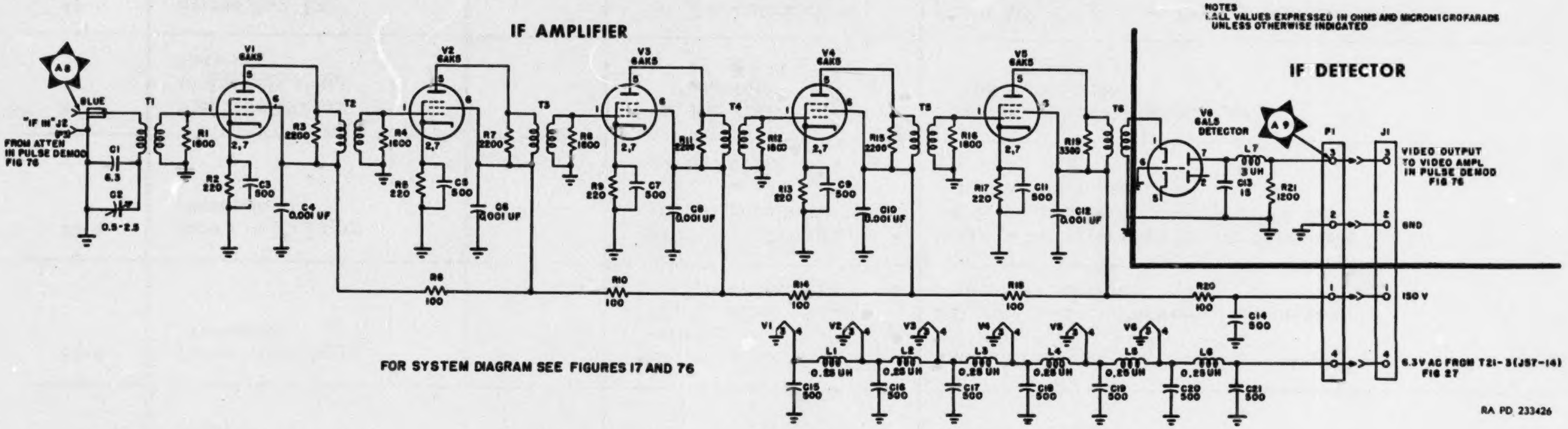
(Continued)

SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS	
				WO/EXP SWEEP	W/EXP SWEEP
59-2	Rate Control (AZ) to Coupling Network (Aided)		E1: 5 AZ Handwheel Drive P1, Pin 1 AZ Coup Net.	Small AC voltage when turning handwheel	
58-2	Rate Control (Elev) to Coupling Network (Aided)		E1: 5 Elev Handwheel Drive P1, Pin 1 Elev Coup Net.	Small AC voltage when turning handwheel	
48-4	Handwheel Drive (Range) to Coupling Network (Man)		B1, Pin 7 Range Handwheel Drive P1, Pin 2 Range Coup Net.	Small AC voltage when turning handwheel	
59-3	Handwheel Drive (AZ) to Coupling Network (Man)		B1, Pin 7 AZ Handwheel Drive P1, Pin 5 AZ Coup Net.	Small AC voltage when turning handwheel	
58-3	Handwheel Drive (Elev) to Coupling Network (Man)		B1, Pin 7 Elev Handwheel Drive P1, Pin 5 Elev Coup Net.	Small AC voltage when turning handwheel	
60 & 61-1	Elevation and Azimuth Coupling Networks to Low Power Servo Amp E_S or A_S (Auto)		P1, Pin 11 Elev Coup Net. P1, Pin 11 AZ Coup Net. P1, Pin 3 LPSAE_S or A_S	Small AC voltage when Balance Modulator is unbalanced	
48-5	Range Motor Feedback to Coupling Network		P1, Pin 3 Range Coupling Network	Small AC voltage when turning handwheel	

(Continued)

SCHEMATIC NUMBER	GRAY BOX	TUBE NUMBERS	CHECK POINT	WAVE FORMS and METER READINGS	
				WO/EXP SWEEP	W/EXP SWEEP
59-4	Int Drive Feedback to Azimuth Coupling Net.		P1, Pin 6 AZ Coupling Net. P1, Pin 8 AZ Coupling Net.	Small AC voltage when turning handwheel	
58-4	Int Drive Feedback to Elevation Coupling Network		P1, Pin 6 Elev Coup Net.	Small AC voltage when turning handwheel	
59-5	Int Drive to Azimuth Coupling Network	(Man and Aid) (Auto)	P1, Pin 2 AZ Coup Net. P1, Pin 3 AZ Coup Net.	Small AC voltage when turning handwheel Small AC voltage when Balance Modulator is unbalanced	
58-5	Int Drive to Elevation Coupling Network	(Man and Aid) (Auto)	P1, Pin 2 Elev Coup Net. P1, Pin 3 Elev Coup Net.	Small AC voltage when turning handwheel Small AC voltage when Balance Modulator is unbalanced	
58-6	Inputs to Int Drive (Elevation)		B2, Pin 1 Elev Int Drive B1, Terminals S1, S2, S3, Elev Int Drive	Small AC voltage when turning handwheel AC voltage varies between 0 and 60 when turning handwheel	
59-6	Inputs to Int Drive (Azimuth)		B6, Pin 1 AZ Int Drive B5, Terminals S1, S2, S3 AZ Int. Drive	Small AC voltage when turning handwheel AC voltage varies between 0 and 60 when turning handwheel	
61-2	Acq Slew Circuit to Azimuth Coup Network		P1, Pin 7 AZ Coup Net.	Small AC voltage when pushing Acq Slew switch	
48-6 58-7 59-7	Stored Rate Input to Handwheel Drive (Range, Elev, AZ) (Auto)		B1, Pin 1 Handwheel Drive (Range, Elev, AZ)	Small AC voltage when Balance Modulators are unbalanced	

Excerpt From TM 9-6092-3-1 SCHEMATIC DIAGRAM


IF AMPLIFIER
IF DETECTOR
A8
BLUE
"IF IN" J2
(P3)
FROM ATTEN
IN PULSE DEMOD
FIG 76
C1
6.3
C2
0.5-2.5
T1
T2
T3
T4
T5
T6
V1
6AK5
V2
6AK5
V3
6AK5
V4
6AK5
V5
6AK5
V6
6AL5
DETECTOR
R1
1800
R2
220
C3
500
R3
2200
C4
0.001 UF
R4
1800
R5
220
C5
500
R7
2200
C6
0.001 UF
R8
1800
R9
220
C7
500
R11
2200
C8
0.001 UF
R12
1800
R13
220
C9
500
R15
2200
C10
0.001 UF
R16
1800
R17
220
C11
500
R19
3300
C12
0.001 UF
R6
100
R10
100
R14
100
R18
100
R20
100
C14
500
L7
3 UH
C13
15
R21
1200
A9
P1
J1
VIDEO OUTPUT
TO VIDEO AMPL
IN PULSE DEMOD
FIG 76
GND
150 V
6.3 V AC FROM T21-3(J57-14)
FIG 27
L1
0.25 UH
L2
0.25 UH
L3
0.25 UH
L4
0.25 UH
L5
0.25 UH
L6
0.25 UH
C15
500
C16
500
C17
500
C18
500
C19
500
C20
500
C21
500

NOTES
1. ALL VALUES EXPRESSED IN OHMS AND MICROMICROFARADS UNLESS OTHERWISE INDICATED

FOR SYSTEM DIAGRAM SEE FIGURES 17 AND 76

RA PD 233426

Figure 75. Tracking IF. amplifier 7614873—schematic diagram.

Excerpt From TM 9-6092-3-2 VOLTAGE AND RESISTANCE CHART

MEASUREMENT NOTES

1. GENERAL

a. It is required that readings be taken with all variable resistors adjusted for normal operation, and all tubes in their sockets.

b. The designation "1, 7" in the pin column indicates that pins 1 and 7 are connected together; "4 to 5" indicates the meter reading is to be taken between pins 4 and 5.

c. A dash indicates a resistance in excess of 10 megohms or a voltage value of no significance.

2. VOLTAGE

a. These measurements are to be made by ordnance maintenance personnel only, following procedures contained in TM 9-6093-4.

b. Measurements shall be taken with a 20,000 ohms/volt dc, 1,000 ohms/volt ac multimeter (TS-352/U or equal), unless otherwise noted, using the scale that permits a reading nearest midscale.

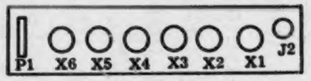
c. All voltages are +dc measured to ground unless otherwise noted.

3. RESISTANCE

a. All resistance values are in ohms and are measured to ground unless otherwise noted.

b. Disconnect all external cables.

c. Connect terminals 1 and 2 of connector P1 to chassis ground with test adapter M (table VII) or equivalent.



BOTTOM VIEW OF CHASSIS

SOCKET NO	TUBE NO	TUBE TYPE	TUBE FUNCTION	PLATE			SUPPRESSOR			SCREEN			CONTROL			CATHODE			FILAMENT		
				Pin	Volts	Res	Pin	Volts	Res	Pin	Volts	Res	Pin	Volts	Res	Pin	Volts	Res	Pin	Volts	Res
X1	V1	6AK5	Amplifier	5	130	500	2,7	2.4	220	6	130	500	1	0	0	2,7	2.4	220	4	6.3 ac	> 0
X2	V2	6AK5	Amplifier	5	132	400	2,7	2.4	220	6	132	400	1	0	0	2,7	2.4	220	4	6.3 ac	> 0
X3	V3	6AK5	Amplifier	5	134	300	2,7	2.4	220	6	134	300	1	0	0	2,7	2.4	220	4	6.3 ac	> 0
X4	V4	6AK5	Amplifier	5	137	200	2,7	2.4	220	6	137	200	1	0	0	2,7	2.4	220	4	6.3 ac	> 0
X5	V5	6AK5	Amplifier	5	140	100	2,7	2.4	220	6	140	100	1	0	0	2,7	2.4	220	4	6.3 ac	> 0
X6	V6	6AL5	Detector	7	-16	1,200										1	0	0	4	6.3 ac	> 0

> Greater than.

RA PD 233585

Figure 84. Tracking IF amplifier 7614273—voltage and resistance chart.

Appendix D

MOS DESCRIPTION

Duties of Heavy Fire Control Equipment Repairman, MOS 232

Inspects, tests, performs, and supervises field maintenance and depot maintenance of heavy integrated electronic fire control equipment. Energizes system and conducts starting procedures and functional check to determine malfunctioning major components such as acquisition radar, tracking radar, computer, tactical control unit, and power control. Utilizes common and special field maintenance electronic test equipment to localize malfunction within a particular major component. Removes malfunctioning chassis or assemblies from the system, and tests and analyzes circuits and circuit elements to determine repairs and replacements required. Repairs or replaces defective chassis and installs chassis in system. Repairs hydraulic systems and mechanical linkage by replacing worn and defective parts such as gears, gear shafts, cams, and gaskets. Alines system by making delicate and complicated adjustments and tests. Performs final inspection and tests system to assure that system and components are operating within prescribed standards and tolerances. Modifies equipment as directed by modification orders. Participates in general shop planning and recommends establishment of procedures for receipt, storage, inspection, testing, and repair of components. Instructs subordinate personnel in on-the-job training programs in the maintenance of test equipment and integrated fire control equipment. Inspects maintenance of using units' fire control systems and associated test equipment. Inspects organizational maintenance methods and procedures and instructs using units' operating personnel on performance of organizational maintenance. Executes or supervises the installation of modifications on using unit and field maintenance equipment as authorized.

Specialist:

Code 232.1—Must know construction, operation, and function of integrated electronic fire control equipment. Must know test operations applicable to integrated fire control systems. Must be able to apply electronic theory in trouble shooting and repair of integrated fire control systems. Must know description and nomenclature of parts and components of integrated fire control equipment. Must be able to interpret and understand schematic diagrams. Must be able to read and understand Technical Manuals and bulletins pertaining to repair of integrated fire control systems and associated equipment. Must be able to use common and specialized electronic test equipment, precision measuring instruments, and electrician's common hand tools. Must know inspection procedures pertaining to organizational maintenance. Must know organizational maintenance policies and procedures and be able to instruct using units' operating personnel in performance of organizational maintenance. Must be able to install modifications on using unit and field maintenance equipment as authorized. Must know precautions to be exercised when working around high voltage. Must be able to instruct subordinate personnel in more difficult phases of locations and correction of malfunctions.

Appendix E

BACKGROUND AND PERFORMANCE DATA

	Aptitude		Education	Performance Subtest Scores			
Student Code Nr	EL	GT	(Years)	Warm-up	Van	Shop	Ord 6
Standard Group							
101	109	124	12	35	096	021	14
102	—	108	13 1/2	23	060	011	15
103	110	125	12 1/2	35	065	019	15
104	113	112	12	44	062	016	13
105	105	133	12	39	067	013	12
106	123	113	13 1/2	48	074	018	14
107	—	116	12	18	097	019	15
108	119	98	10	39	069	016	10
09	120	119	13 1/2	36	090	017	12
110	115	126	12	58	110	014	16
111	114	115	11	41	058	016	15
112	113	115	11	33	067	014	14
113	92	105	15 1/2	49	061	015	12
114	105	117	12	41	046	014	13
115	126	116	13	64	112	016	16
116	135	111	12	48	078	018	10
117	129	123	12	27	069	014	16
Experimental Group							
201	115	118	11	29	057	018	16
202	126	126	10	35	074	013	16
203	109	114	10	53	083	015	16
204	119	120	12	30	074	019	16
205	106	119	12	27	069	021	16
206	147	130	12	45	080	018	16
207	127	129	12	42	102	018	16
208	97	119	12	41	039	022	16
209	122	119	12	41	110	029	16
210	88	117	12	35	079	025	16
213	113	104	12	41	072	022	16
214	102	111	11	17	056	010	16
216	90	114	12	41	062	019	16
217	98	105	12	36	078	019	16
218	91	114	12	52	067	013	16
219	94	106	12	31	084	024	16
220	121	116	11	35	078	020	16
222	107	110	12	35	065	019	16
223	109	119	12	29	064	019	16
224	81	100	11	29	062	015	16

Appendix F

SUMMARY OF PILOT STUDIES

Pilot studies played a central role in the FORECAST research. These pilot studies were small-scale models of aspects of the final training program and were used only to structure the validation study. The objectives of these studies were to (1) provide reasonably reliable information and (2) provide a large amount of information in a short time. As these two aims tend to be incompatible, the balance between them was achieved judgmentally.

Numerous questions were posed in the FORECAST I pilot studies. The primary question asked in each was, "How much time should be devoted to each aspect of training?" A second question was, "What equipment and training aids are needed?", and a third, "What measures of the student's mastery of training materials are appropriate?" Other questions asked were specific to one study or to a subgroup of pilot studies. Finally, the studies were used to train the instructors to be used in the validation study.

Operator Studies A Through H, 1956-1957

Fifty metropolitan Washington high school students were used in this series of eight pilot studies. The students' tasks were to learn certain operator procedures which consisted of operating certain switches and knobs in a prescribed sequence.

The experimenters presented various "stories" regarding the way in which these knobs and switches, as well as certain meters and lights, were related to each other in the circuitry behind the panels on which they were mounted. It became clear in these studies that the kind of "story" used did not produce differences of any consequence in the speed of learning to operate the controls in the prescribed sequence. In fact, students learned as fast without a story as with one. However, it was found that the presentation of a story reduced the amount of practice time needed on the equipment. This information was used in subsequent pilot studies as well as in the validation study.

In later studies of this series, students were exposed to verbal descriptions of the equipment and relations between its parts without the equipment being present. This procedure had the practical advantage of reducing the amount of equipment needed to train a group of students and did not appreciably affect speed of learning.

Maintenance Study I, 4-8 Nov 57

A series of four pilot studies in which military enlisted men were used as subjects was also conducted. Maintenance Study I used five military subjects whose GT scores ranged from 95 to 109; the duration of the study was one week. In addition to the over-all training questions already mentioned, this study was aimed at answering three specific questions. The questions and the resulting answers were:

Question 1: Would military students react to instruction the same way as had the high school students?

Answer 1: The class results were similar to those obtained with high school students, but it was felt that motivation was lower.

Question 2: Did the class react to a female instructor in an unusual manner?

Answer 2: No unusual reactions were noted with respect to the female instructor.

Question 3: What is the relationship between intelligence (as measured by GT scores) and classroom performance?

Answer 3: The relationship between intelligence and performance could not be determined for so small a group but the indication was that the relationship would not be high in a large population.

In addition to answering these questions this pilot study had the following objectives: (1) to begin adjustment of the training program to The Ordnance School classroom schedule (50-minute blocks of instruction) and (2) to begin training an officer instructor.

Maintenance Study II, 14-22 Nov 57

Five military students with GT scores ranging from 84 to 119 were studied. Their educational backgrounds ranged from one to four years of high school. The duration of the class was eight days.

The same questions were asked in Maintenance Study II as in the first study and the objectives were the same. The answers were essentially the same except in regard to the relation of GT scores and classroom performance. In this class three men with the highest GT scores learned much faster than the two with the lowest scores, who presented instructional problems. The speed of presentation was held to the faster pace and the two low men fell behind. It was decided at this time that there should be no attempt to train men with GT scores below 90 in the validation study before investigating the problem of the low GT more carefully. (This still remains to be done.)

An "electrical" question box was tried out in this study. This instrument allowed all students to answer each question asked by the instructor without knowledge of each other's answers. The question box was introduced to help solve the motivation problem noticed in Maintenance Study I. It appeared to work well.

The students were allowed to operate the M33 equipment and make some adjustments after the classroom instruction.

The training of the officer instructor was completed. No differences in content of instruction or student reaction could be noted for this instructor in comparison with the female instructor in the first study.

Maintenance Study III, 3-18 Dec 57

In the third study seven military students with GT scores from 100 to 133 were studied. (The duration of the study was nine days and included 35 1/2 hours of lecture, 44 hours of practical work on the M33, and 5 1/2 hours of testing.) This class was the first to trouble shoot the M33 after learning the classroom material. The program of instruction (POI) for the Track subsystem was beginning to take on its final form. In order to give the students sufficient information to trouble shoot, the POI had to include practical subjects which had not been taught before. Therefore, instruction was initiated on the use of tube tester, meters, location of chassis in equipment, and more accurate definitions of symptoms.

Generally speaking, the class was considered easy to teach and quick to learn. There were no questions formulated specifically for the study. It was assumed that certain aspects of training had been overlooked, and this study was used to identify these oversights. The oversights showed up either in the students' classroom questions or in the failure of students to perform all aspects of trouble shooting. The following oversights were found:

Symptoms. Students had little difficulty in retaining descriptions of symptoms from the classroom because they recognized them on the equipment when performing their trouble shooting. It was found, however, that some of the symptoms defined in class did not appear in the defined manner on the equipment. Corrections had to be made in those symptom definitions.

Chassis Location. It appeared to be difficult for students to remember the spatial locations of chassis in the equipment. Some men were seen drawing location diagrams in their notebooks. On the basis of this observation, chassis location diagrams were prepared for the next class. Also, the block diagram was rearranged so that the blocks would correspond more closely with their spatial location in the equipment.

Meter Symptoms. Symptoms which appeared on meters were not well retained from classroom instruction. It was decided that in the future students would be shown meter symptoms and all other symptoms on the equipment the first day they started training. They learned to operate the equipment the first day and the symptom training was added to this period of instruction.

Adjustments. The lesson plan on adjustments was not complete.

Trouble Shooting Performance. Only tube malfunctions (Track subsystem) were introduced during this study. By the end of the study the students required an average of less than 10 minutes to identify malfunctioning tubes. The average trouble shooting time was considered good by the experimenters. This was the first clear indication of the effectiveness of the training program.

Electrical Question Box. Although the electrical question box proved to be effective for this class, the research staff decided to discontinue its use. It was considered more important to maintain equal training conditions for standard and experimental groups than to obtain better performances from the experimental students through the use of the device.

Maintenance Study IV, 7-22 Jan 58

Eight military students with GT scores from 90 to 119 were trained for two weeks. This study was considered the dress rehearsal for the final study. It was similar to Maintenance Study III and had the same objectives. The students were required to trouble shoot to the tube level as during a test period, as in the third study. They did not trouble shoot to other replaceable parts (e.g., resistors, capacitors) as there was no time to prepare malfunctioning parts for a test. Therefore no evidence that students could trouble shoot to parts was obtained in the pilot study series. The class was held an additional two days for a special study.

The following findings were noted:

(1) The layout of the new block diagram, designed on the basis of Maintenance Study III results, appeared to make the block diagram harder for the students to learn than the unrevised version. It also appeared that the block diagram layout did not achieve the improvement in memorization of chassis locations that it was designed to produce. Students had as much trouble finding the location of chassis as they had before the diagram was changed. It was concluded that learning the spatial location of chassis would take a few hours and there was no point in trying to further reduce this time by developing a third layout. The version of the layout used in this pilot study was used in the final study.

(2) Experience suggested that the students would be able to trouble shoot faster if the wave forms were printed on the block diagrams. The evidence for this was the observation that students spent a considerable portion of their time changing their attention from block diagrams to wave form charts during trouble shooting. This revision was not accomplished as it was too close to the scheduled start of the final study.

(3) It seemed likely that colored overlays for the block diagrams would aid students in learning them. This was not done because of the shortage of time before the final study.

(4) Even with the relatively narrow range of GT scores in this class (90-119), differences in the speed with which students absorbed information were noted. This finding led to the "two-track" training system used in the final study. It was desired to have the 24 students in the final study graduate at different times. Therefore the 24 students were divided into two groups on the basis of GT scores. The students with lower scores were placed in the class which lasted two weeks longer (12 weeks) than the class for the high GT group.

(5) It was felt that motivation was lower than it would have been had an MOS been awarded the students at graduation. The project officer noted considerable concern about this point among the students. He made a strong recommendation that an MOS 232.1 be awarded the

students in the final class. Unfortunately, this proved to be impossible for administrative reasons.

(6) It was decided to post class grades conspicuously in the final study.

(7) Certain portions of the check point tables and schematic diagrams were either incomplete or incorrect. The definitions of adjustments were not sufficiently accurate.

(8) The students did well in their trouble shooting tests. The average time to locate malfunctioning tubes was about 10 minutes.

(9) After being tested the students were presented with one and a half days of special instruction on the generalizations regarding various components of the system. This material was prepared and presented by one of the staff members. The experienced instructors who observed this instruction felt that no judgment of the value of emphasizing these generalities was possible, as the class tended to resist the instruction.

Appendix G

MASTER TRAINING SCHEDULE FOR THE EXPERIMENTAL COURSE

The Master Training Schedule in this appendix was used for the experimental training program. Minor deviations from the schedule were necessary because of the administrative and equipment requirements.

Sections A and B included students with high General Technical scores; they received instruction on all but the last day of the first 10 weeks of the experimental training period. Sections C and D consisted of students with low GT scores; they were given the 12 weeks of instruction.

Abbreviations are used in the schedule as follows:

Abbreviation	Meaning
A, B, C, D	section letter—6 students per section
Acq	acquisition
Adj	adjustments
Ant	antenna
BD	block diagram
Blk	block
C/c	concurrent
Cha	chassis
Comp	computer
Dia	diagram
Elect	electronic
Elem	elements
Empl	emplacement
Equip	equipment
Func	functional
Gen	generator
Heat	heating
Hyds	hydraulics
(Instructors' names)	
Cla	Pfc Clark
Kir	Pfc Kirby
Kri	Mr. Kries
McB	Sgt McBride
Ras	Pfc Rasmussen
Wea	Pfc Weaver
Intro	introduction
L1, L2, L3, L4	laboratory number
Lgt	light
Malf	malfunctions
Mar Ord	march order
Misc	miscellaneous
Mod	modulator
Nav	navigation
Oper	operator
Orient	orientation
Peri	periscope
Plot Bd	plotting board
Prev Mnt	preventive maintenance
Proc	procedure(s)
Recap	recapitulation
Sup	supplies
SWB	switchboard
Symp	symptoms
Synchro	synchronization
TFI	trial fire indicator
Tng	training
Trk	track
TS	trouble shooting
Vent	ventilation

1st Week

	21 Apr 58	22 Apr 58	23 Apr 58	24 Apr 58	25 Apr 58
SECTION	A B C D	A B C D	A B C D	A B C D	A B C D
0800 to 0850	**Orientation** Lt Fox Classroom	**Block Diagram** Miss Rund Classroom	**Block Diagram** Miss Rund Classroom	**Symptoms** Miss Rund Classroom	**Schematic Symbols** Lt Fox Classroom
0900 to 0950	**Operator Training** Ras Wea Kir Cla L1 L2 L3 L4	"	"	"	**Color Code & Symbols Test** Pfc Weaver Classroom
1000 to 1050	" " " "	"	**Block Diagram Test** Pfc Rasmussen Classroom	**Meter Symptoms** Lt Fox L1	**Soldering** Lt Fox Classroom
1100 to 1150	" " " "	"	"	**Symptoms** Lt Fox Classroom	**Schematics (Theoretical)** Lt Fox Classroom
1300 to 1350	**Block Diagram** Miss Rund Classroom	"	**Symptoms** Miss Rund Classroom	"	**Schematics (General)** Lt Fox Classroom
1400 to 1450	"	"	"	**Symptoms Test** Pfc Weaver Classroom	**Test Equipment** Sgt McBride L1
1500 to 1550	"	"	"	**Check Points** Miss Rund Classroom	**Chassis Navigation** Lt Fox Ras Wea Kir Cla Classroom
1600 to 1650	"	"	"	**Symptoms to Gray Boxes** Miss Rund Classroom	**TS Procedure** Lt Fox Classroom
EQUIP. RECAP:	1 Classroom 4 Labs	1 Classroom	1 Classroom	1 Classroom 1 Lab	1 Classroom 1 Lab 12 Soldering irons 12 Chassis

2d Week

	28 Apr 58				29 Apr 58				30 Apr 58				1 May 58				2 May 58			
SECTION	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0800 to 0850	Track TS (Tube Malf) Ras L1	Wea L2	Kir L3	Cla L4	Track TS (Tube Malf) Ras L1	Wea L2	Kir L3	Cla L4	Track TS (Tube Malf) Ras L1	Kir L2	Kri L3	Cla L4	Track TS (Cha Malf) Wea & Ras L 1&2	Kri & McB L 3&4	Track Review Miss Rund Classroom		Track TS (Cha Malf) Kri & Wea L 1&2	Cla & Kir L 3&4	Track Review Miss Rund Classroom	
0900 to 1150	Soldering C/c Tng				Cha Nav C/c Tng				Cha Nav C/c Tng				Cha Nav C/c Tng		"		Cha Malf C/c Tng		"	
1300 to 1450	"				"				"				"		"		"		"	
1500 to 1550	"				"				OPEN TIME				"		"		Track Adj Sgt McBride L1		"	
1600 to 1650	OPEN TIME				OPEN TIME				"				OPEN TIME				OPEN TIME			
EQUIP. RECAP:	4 Labs 12 Soldering irons 12 Multimeters				4 Labs				4 Labs				4 Labs 1 Classroom				4 Labs 1 Classroom			

3d Week

	5 May 58				6 May 58				7 May 58				8 May 58				9 May 58			
SECTION	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0800 to 0850	Acq BD Ras Classroom		Trk TS (Tube Malf) Wea L1	Kir L2	Acq BD Ras Classroom		Trk TS (Cha Malf) Wea L1	Kir L2	Acq Symp Ras Classroom		Trk TS (Cha Malf) Wea L1	McB L2	Acq TS McB L3	Cla L4	Trk TS Kir L1	Wea L2	Acq TS Kir L3	Cla L4	Trk TS Fox L1	Rund L2
0900 to 0950	"		Cha Nav C/c Tng		"		Cha Malf C/c Tng		"		"	"	"	"	"	"	"	"	Trk Adj McB L1	
1000 to 1150	"		"		Acq BD Test Cla Classroom		"		"		"	"	"	"	"	"	"	"	"	
1300 to 1350	"		"		Dia Map Tracking Classroom		"		"		"	"	"	"	"	"	"	"	"	
1400 to 1450	"		"		"		"		Acq Symp Test Cla Classroom		"	"	"	"	"	"	"	"	"	
1500 to 1550	"		"		Acq Symp Ras, L3 Classroom		"		Synchro & Servo Systems for Acq & Trk		"	"	"	"	"	"	"	"	"	
1600 to 1650	OPEN TIME				OPEN TIME				OPEN TIME				OPEN TIME				OPEN TIME			
EQUIP. RECAP:	2 Labs 1 Classroom				3 Labs 1 Classroom				2 Labs 1 Classroom				4 Labs				4 Labs			

4th Week

	12 May 58				13 May 58				14 May 58				15 May 58				16 May 58			
SECTION	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0800 to 0850	Acq TS Kri L3	Cla L4	Acq BD Ras Classroom		Acq TS Kri L3	Kir L4	Acq BD Ras Classroom		Acq TS Kri L3	Cla L4	Acq Symp Ras Classroom		Acq TS Kri L3	Kir L4	Acq Symp Ras Classroom		Acq TS McB L3	Kir L4	Acq TS Cla L1	Fox L2
0900 to 0950	"	"	"		"	"	BD Test Cla Classroom		"	"	"		"	"	Acq Symp Test Cla Classroom		"	"	"	"
1000 to 1050	"	"	"		"	"	"		"	"	"		"	"	Servos & Synchro for Acq & Trk Kri		"	"	"	"
1100 to 1150	"	"	"		"	"	Dia Map Tracing Classroom		"	"	"		"	"	"		"	"	"	"
1300 to 1350	"	"	"		"	"	"		OPEN TIME		"		"	"	Acq TS Cla L1	McB L2	"	"	"	"
1400 to 1450	"	"	"		"	"	Acq Symp Ras Classroom		"		"		"	"	"	"	"	"	"	"
1500 to 1650	"	"	"		"	"	"		"		"		"	"	"	"	Acq Adj McB L3		"	"
EQUIP. RECAP:	2 Labs 1 Classroom				2 Labs 1 Classroom				2 Labs 1 Classroom				4 Labs 1 Classroom				4 Labs			

5th Week

	19 May 58				20 May 58				21 May 58				22 May 58				23 May 58			
SECTION	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0800 to 0850	Comp Intro Miss Rund Classroom		Acq Ras L1	TS Cla L2	Comp Panels Miss Rund Classroom		Acq Ras L1	TS Kir L2	Comp Zero Set Miss Rund Classroom		Acq McB L1	TS Cla L2	Comp Tests Wea Classroom		Acq McB L1	TS Kir L2	Comp Wea L1	TS Kir L2	Acq Ras L1	TS Cla L2
0900 to 0950	Intro & Comp Elem Miss Rund		"	"	"		"	"	Plot Bd Wea		"	"	Comp & TFI Tests Wea		"	"	"	"	"	"
1000 to 1150	Computer Block Diagram		"	"	Functional Diagrams		"	"	Functional Plot Dia Miss Rund		"	"	Power Supply Miss Rund Classroom		"	"	Power Supply & Mod Adj		"	"
1300 to 1350	"		"	"	Schematics		"	"	"		"	"	Review		"	"	"		"	"
1400 to 1450	Test (Ques & Ans)		"	"	"		"	"	Comp Tests Miss Rund		"	"	"		"	"	"		"	"
1500 to 1550	Oper Tng L3		"	"	"		"	"	Comp Tests Miss Rund L1		L2		"		"	"	"		"	"
1600 to 1650	Oper Tng L1	L3	L2		Test Schematics		"	"	OPEN TIME		"		"		"	"	"		"	"
EQUIP. RECAP:	3 Labs 1 Classroom				2 Labs 1 Classroom				2 Labs 1 Classroom				2 Labs 1 Classroom				2 Labs 1 Classroom			

6th Week

	26 May 58				27 May 58				28 May 58				29 May 58				30 May 58			
SECTION	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0800 to 0850	Comp Wea L1	TS Kir L2	Computer Miss Rund Classroom		Comp Cla L1	TS Kir L2	Computer Miss Rund Classroom		Comp Cla L1	TS Wea L2	Computer Miss Rund Classroom		Comp Rund L1	TS Kir L2	Power Supply & Mod Adj Miss Rund			HOLIDAY		
0900 to 1050	"	"	"		"	"	"		"	"	"		"	"	Comp McB L3	TS Cla L4		"		
1100 to 1150	"	"	"		"	"	"			OPEN TIME			"	"	"	"		"		
1300 to 1650	"	"	"		"	"	"		Comp Cla L1	TS Wea L2	Computer Miss Rund Classroom		"	"	"	"		"		
EQUIP. RECAP:	2 Labs 1 Classroom				2 Labs 1 Classroom				2 Labs 1 Classroom				4 Labs							

7th Week

	2 Jun 58				3 Jun 58				4 Jun 58				5 Jun 58				6 Jun 58			
SECTION	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0800 to 0850		HOLIDAY			Supply Proc McB L1		Van Heat Lgt Vent Kri Classroom		Ant McB L1	Hyd Kri L2	Van TS Ras & Cla Van 1&2	Comp TS Kir L3	Power Supply McB L1	Kri L2	Van TS Cla & Ras Van 1&2	Comp TS Wea L3	March Order Emplacement McB Classroom		Comp TS Kir L3	Van Prev Mnt Wea & Cla Van 1&2
0900 to 0950		"			T-34 Peri McB L1		SWB Kri Classroom		"	"	"	"	"	"	"	"	"		"	Gen Kri Blk 27

(Continued)

7th Week *(Continued)*

	2 Jun 58				3 Jun 58				4 Jun 58				5 Jun 58				6 Jun 58			
SECTION	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
1000 to 1050		HOLIDAY			T-34 Peri McB L1		Prev Mnt Kri Classroom		Ant Hyd McB L1	Kri L2	Van TS Ras & Cla Van 1&2	Comp TS Kir L3	Power Supply McB L1	Kri L2	Van TS Cla & Ras Van 1&2	Comp TS Wea L3	March Order Emplacement McB Classroom		Comp TS Kir L3	Gen Kri Blk 27
1100 to 1150		"			Ant Hyds McB L1	Kri L2	OPEN TIME		Power Supply McB L1		"	"	"	"	"	"	"		"	Van TS Wea & Cla Van 1&2
1300 to 1450		"			"	"	Van Prev Mnt Ras & Cla Van 1&2	Comp TS Kir L3	"		"	"	"	"	"	"	Orient & Synchro McB L1	Kri L2	"	"
1500 to 1550		"			"	"	Generator Kri Blk 27		"		"	"	"	"	"	"	"	"	"	"
1600 to 1650		"			"	"	"		"		"	"	OPEN TIME		"	"	"	"	"	"
EQUIP. RECAP:					3 Labs 1 Classroom 2 Vans				3 Labs 2 Vans				3 Labs 2 Vans				3 Labs 1 Classroom 2 Vans			

8th Week

	9 Jun 58				10 Jun 58				11 Jun 58				12 Jun 58				13 Jun 58			
SECTION	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0800 to 0950	**Ord 6** **Test Equip** Fox Kri Ord 6		**Comp** **TS** Wea L3	**Van** **TS** Kir & Ras Van 1&2	**Ord 6** **Test Equip** Ras & McB Ord 6		**Comp** **TS** Kri L1	**Van** **TS** Kir & Cla Van 1&2	**Van TS** McB & Wea Van 1&2	Ras & Kri Van 3&4	**Comp TS** Rund L1	Kir L2	**Van TS** Ras & Kri Van 1&2	Fox & Wea Van 3&4	**Ord 6** McB (Cla) Ord 6		**Van TS** Kri & Kir Van 1&2	Wea & Fox Van 3&4	**Ord 6** McB (Cla) Ord 6	
1000 to 1050	"		"	"	"		"	"	**Van Heat** **Lgt Vent** McB		"	"	"	"	"		"	"	"	
1100 to 1150	"		"	"	**OPEN TIME**				"	"	"	"	"	"	"		"	"	"	
1300 to 1350	"		"	"	"		"	"	**SWB** McB Blk 27		**Plot Bd**		"	"	"		"	"	"	
1400 to 1450	"		"	"	"		"	"	**Prev Mnt** McB Blk 27		**Data Comp**		"	"	"		"	"	"	
1500 to 1650	"		"	"	"		"	"	**Generator** McB Blk 27		**Misc Adj** Miss Rund		"	"	"		"	"	"	
EQUIP. RECAP:	1 Lab 2 Vans Ord 6				1 Lab 2 Vans Ord 6				2 Labs 4 Vans				Ord 6 4 Vans				Ord 6 4 Vans			

9th Week

	16 Jun 58				17 Jun 58				18 Jun 58				19 Jun 58				20 Jun 58			
SECTION	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
0800 to 1150	Van TS Ras & Wea Van 3&4	Cla & Kir Van 1&2	Elect Terms & Meanings Dr. Shriver Classroom		Van TS Ras & Wea Van 1&2	Cla & Kir Van 3&4	OPEN TIME		Van TS Ras & Wea Van 1&2	Cla & Kir Van 3&4	OPEN TIME		Elect Terms & Meanings Dr. Shriver Classroom		Van TS Wea & Cla Van 1&2	Ras & Kir Van 3&4	OPEN TIME		Van TS Wea & Cla Van 1&2	Ras & Kir Van 3&4
1300 to 1650	"	"	"		"	"	"		OPEN TIME		Van TS Ras & Wea Van 1&2	Cla & Kir Van 3&4	"		"	"	"		"	"

10th Week

	23 Jun 58				24 Jun 58				25 Jun 58				26 Jun 58				27 Jun 58	
SECTION	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	C	D
0800 to 1150	System TS Ras L1	Cla L2	System TS Kir L3	Wea L4	System TS Wea L1	Ras L2	System TS Cla L3	Kir L4	System TS Kir L1	Wea L2	System TS Ras L3	Cla L4	System TS Cla L1	Kir L2	System TS Wea L3	Ras L4	System TS Kir L3	Wea L4
1300 to 1450	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
1500 to 1650	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	OPEN TIME	

11th Week

	30 Jun 58		1 Jul 58		2 Jul 58		3 Jul 58		4 Jul 58	
SECTION	C	D	C	D	C	D	C	D	C	D
0800 to 0850	Sup Proc McB L1		Ant Hyds McB L1	Kri L2	Power Sup McB L1	Kri L2	Power Sup McB L1	Kri L2	OPEN TIME	
0900 to 1050	T-34 Peri McB L1		"	"	"	"	"	"	"	
1100 to 1150	Ant Hyds McB L1		Power Sup McB L1		"	"	"	"	"	
1300 to 1450	Ant Hyds McB L1	Kri L2	"		"	"	Orient & Synchro Kri L1		"	
1500 to 1550	OPEN TIME		"		"	"	"		"	
1600 to 1650	"		"		OPEN TIME		"		"	

12th Week

	7 Jul 58		8 Jul 58		9 Jul 58		10 Jul 58		11 Jul 58	
SECTION	C	D	C	D	C	D	C	D	C	D
0800 to 1150	System TS Wea L1	Kir L2	System TS Rund L1	Kir L2	System TS Wea L1	Rund L2	System TS McB L1	Wea L2	System TS McB L1	Kir L2
1300 to 1350	Empl & Mar Ord Kri L1		"	"	"	"	"	"	"	"
1400 to 1550	"		"	"	Comp Adj McB L1		"	"	"	"
1600 to 1650	"		"	"	OPEN TIME		"	"	"	"

Appendix H

DISTRIBUTION OF INSTRUCTIONAL HOURS[1]
(Average of All Four Instructional Sections)

Miss Rund	
Track Classroom Instruction	20
Track Review[2]	16
Computer Classroom Instruction	20
Trouble Shooting (Laboratory)	16
	72

Sgt McBride	
Test Equipment	1
Track Adjustments	2
Computer Tests Demonstration	1
Computer Adjustments	2
Ord 6	16
Supply Procedures	1
T-34 Periscope	2
Antenna Hydraulics	6
Power Supply (Conference)	4
Power Supply (Laboratory)	8
Orientation and Synchronization	4
Trouble Shooting (Laboratory)	24
	71

Pfc Rasmussen	
Track Block Diagram Examination	2
Acquisition Block Diagram	9
Acquisition Symptoms	10
	21

Mr. Kries	
Servos and Synchros	2
Van, Heat, Light, and Ventilation	1
Switchboard	1
Preventive Maintenance (Conference)	1
Hobart Generator	2
Emplacement and March Order	4
Orientation and Synchronization	4
Chassis Navigation	4
	19

Dr. Shriver	
Basic Electronics	8
Questionnaires and Tests	4
	12

Pfc Weaver	
Color Code	1
Track Symptoms Examination	1
Computer Block Diagram Examination	1
Computer Operator Training	2
Computer Panels	2
Computer Schematics Examination	1
Plotting Board Block Diagram	1
Computer Tests Examination	1
	10

Lt Fox	
Track Meter Symptoms	1
Schematic Reading	3
Soldering	1
Chassis Navigation	1
Trouble Shooting Procedure	1
	7

Pfc Clark	
Acquisition Block Diagram Examination	2
Acquisition Symptoms Examination	1
	3

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[1] All laboratory trouble shooting instruction other than that indicated for Miss Rund and Sgt McBride totaled about 200 hours on the average. This instruction was given by Pfc Rasmussen, Pfc Weaver, Pfc Clark, Pfc Kirby, and Mr. Kries.

[2] Given to half the students only.

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